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THE SCIENTIFIC MONTHLY

FEBRUARY, 1929

PRESENT TENDENCIES IN BIOLOGICAL THEORY[1]

By Professor WILLIAM MORTON WHEELER

BUSSEY INSTITUTION, HARVARD UNIVERSITY

> Ainsi, l'être vivant ne constitue pas une exception a la grande harmonie naturelle qui fait que les choses s'adaptent les unes aux autres; il ne rompt aucun accord; il n'est ni en contradiction ni en lutte avec les forces cosmiques générales; bien loin de là, il fait parti du concert universel des choses, et la vie de l'animal, par exemple, n'est qu'un fragment de la vie totale de l'univers.
>
> —*Claude Bernard.*

Most scientific investigators are, no doubt, satisfied with the course of development and optimistic in regard to the future of their own specialties. There are always theorists, however, who, in an endeavor to view particular sciences as wholes, find cause for considerable dissatisfaction with their existing condition and tendencies, and biology is most liable to become the object of such disparagement, especially during periods like the present when the adjacent physico-chemical sciences are undergoing revolutionary and brilliant transformation. Some dwell on the deplorable "Zersplitterung" and dearth of adequate theory in the life-science (*e.g.*, Schaxel[2]). One erratic historian, Radl,[3] finds that biology has been steadily going to the dogs ever since the Renaissance, though it is clear, as Whitehead has noticed, that "the biological sciences as effective schemes of thought are barely one hundred years old."[4] Another recent theorist, Bertalanffy,[5] believes that biology has about reached a stage corresponding with pre-Copernican astronomy and physics, and maintains that the biologists have not yet discovered a single law, that what they have been fondly calling laws are merely rules or generalizations. He would probably regard the "biogenetic law" as little more than an inference or conjecture. As proof of his contention he instances the frequent naming of physical laws after their discoverers and the absence of this practice among biologists, except, of course, when they mistake mere rules for laws as in the case of Mendelism. Indeed, one infers that biologists, unlike physicists, do not understand the meaning of scientific legality and would not recognize a law if they saw one. Not only have they failed to secrete the proper theoretical cohesive for their in-

[1] Address given by invitation at a general session of the American Association for the Advancement of Science, American Museum of Natural History, New York, December 29, 1928.

[2] J. Schaxel, "Grundzüge der Theorienbildung in der Biologie," 2 Aufl. Jena, 1922, p. 1, *ff.*

[3] E. Radl, "Geschichte der biologischen Theorien in der Neuzeit," 2 Aufl. Vol. 1, 1913, p. 147, 161, 270, etc.

[4] A. N. Whitehead, "Science and the Modern World," London and New York, 1925, p. 141.

[5] L. Bertalanffy, "Kritische Theorien der Formbildung," Berlin, 1928.

numerable and highly heterogeneous data, but they are still addicted to the use of a medieval and Aristotelian glue compounded of such antiquated ingredients as Cartesian mechanics, potentialities, dispositions, determinants, instincts, impulses and purposes. And to increase our discomfort, we are warned by some theorists that unless we make haste and produce a few Einsteins who can furnish a sound scientific foundation for individual and social ethics, economics, politics and human genetics, our whole race will be asphyxiated under the flood of machines and other contraptions that keep pouring down on us from the fecund womb of technology. The theorists therefore speak of the present state of biology as a crisis, but they make it look more like a mess. Perhaps we ought to study the situation.

We must ruefully admit, I believe, that biology does present an appearance of extreme confusion. This is manifestly due in part to the inconceivable intricacy of the sector of reality which the biologists have undertaken to explore and partly to the situation of this sector midway between physics and chemistry on the one hand and philosophy on the other. This situation has both its advantages and disadvantages, and one of the latter is certainly the discomfort which the investigator, who is necessarily a specialist, suffers from exposure to so many winds of doctrine, blowing from such diverse quarters. Some of these winds, laden with the heady odors of relativity and atomic theory, now blow steadily from the domains of physics and cosmogony, while others, more intermittent, and saturated with staler effluvia, blow from the quagmires of epistemology and metaphysics, and, of course, we must not forget the odoriferous doctrinal gusts that are always rising from the more active portions of the biological field itself. How can we blame the investigator if he complains of the draughts and hurries away to the seclusion of his own specialty?

Yet the theorists may be right in censuring this behavior on the ground that the investigator needs the open air, even if it is not always very fresh. We are reminded that it is neither the observational and experimental data nor the investigational methods, but the theories that are the essential, vital constituents of a science. It would be easy to show that they can not be dispensed with, however circumscribed the problem of research, and it would be almost as easy to show that an abiding interest in the more comprehensive theories—those conceived in the grand manner—is all that prevents our sciences from lapsing into little more than empirical routines. I need hardly say that I am employing the word theories in this paper in a very broad sense to include also hypotheses, generalizations and fictions, as that word is used by Vaihinger in his philosophy of the "as-if," a polite substitute for the phrase "lies, damned lies and statistics." Since we seem to be justified in concentrating on the regnant theories of a science as the best expression of its tendencies during any particular period, the discussion may be largely confined to a consideration of some of the dominant theoretical interests in present-day biology.

We might divide the tendencies into three groups: those which biology in the broadest sense shares with all the other sciences, those peculiar to particular biological sciences and those that originate either in some one of the latter or in some non-biological science and tend to spread over the whole biological domain. Well-known tendencies common to all the sciences at the present time are, of course, the prodigious accumulation of empirical data and the intense specialization and differentiation of the methods and devices for penetrating reality that are demanded by the investigator's urge for more critical

analysis of phenomena. The tendencies in the various biological sciences exhibit extraordinary diversity. Some of the older sciences, like taxonomy, have become largely routine accumulation of data and their discriminative refinement and systematization, while others, like genetics, are heaving with instability and display what Schaxel has called "eine theoretische Verwilderung." In some of the sciences the births and deaths of hypotheses succeed one another with truly modern, if not always commendable speed, while the hypotheses that can maintain their vigor seek to preempt as much as possible of biological thought. Some of these hypotheses are, of course, emulative, fanciful or merely imitative, but probably none of them is altogether useless. There are also what might be called negative tendencies, such as the deficiency of historical sense, which characterizes our whole civilization and may be due, as Tilgher has suggested, to the gradual rising to control of a new social class, the proletariat, just as the eighteenth century's neglect of history was due to the rise of the bourgeoisie.

Sociology
Psychology
Anthropology
Ethology
Pathology
Physiology
Genetics
Morphology
Paleontology
Biogeography
Phylogenetics
Taxonomy

It would be impossible in the time at my disposal even to catalogue the more important theories that are peculiar to the various biological sciences, and I am surely incompetent to discuss them. All I can attempt is a rather impressionistic sketch of the theoretical conceptions that have had sufficient vitality, enterprise and generality to dominate large portions of the whole biological field. This sketch will acquire somewhat sharper contours if we begin with a list of the dozen odd biological sciences, arranged according to their more obvious affinities.

It will be granted that all these sciences have acquired considerable independence notwithstanding their complicated interrelations and that they might best be represented diagrammatically in the three dimensions of space. For my purpose, however, a simple serial arrangement will suffice, with sociology

Taxonomy
Phylogenetics
Biogeography
Paleontology
Morphology
Genetics
Physiology
Pathology
Ethology
Anthropology
Psychology
Sociology

and psychology, if we insist on their inclusion, at the top and phylogenetics and taxonomy at the bottom. But any arrangement of this kind at once arouses our sense of values, if only because first and last suggest superiority and inferiority. The sociologists and psychologists would say that this arrangement is quite acceptable, though they might differ as to which of their

respective sciences should head the list. The physiologist, too, might be satisfied and contend that his science is naturally at the very heart of the whole series, or he might liken the list to a ladder extending from the earth's interior to the heavens, with the sociologists and psychologists among the clouds, the taxonomists and phylogeneticists in the waters under the earth with the other blind fish, and himself alone with his feet solidly planted on the lithosphere. The dissatisfied taxonomist, however, might insist that the whole series should be inverted and likened rather to the ascending scheme of the Divine Comedy. He might say that the writhing and vociferous psychologists and sociologists should be consigned to the Inferno, that the physiologists and their neighbors, the geneticists, belong together with their caged and vivisected animals in the Purgatorio and that the taxonomists alone abide in the opalescent effulgence of the Paradiso among the Platonic ideas and essences which from time to time deign to descend as the species and genera to incorporate themselves in the organic individuals. Fortunately, we

Sociology
Psychology
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Ethology
Pathology
Physiology
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Morphology
Paleontology
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Phylogenetics
Taxonomy

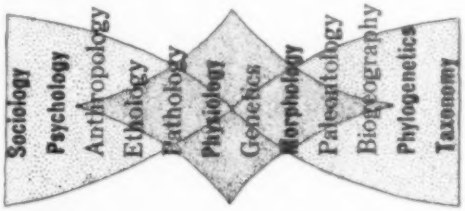
can avoid these unhappy evaluative dissentions by simply turning our original series through an angle of 90° and likening it in its new position to a spectrum, an advancing army or a parliamentary body with a right, conservative wing (taxonomy and phylogenetics), a left, radical wing (sociology and psychology) and a Catholic center (physiology and genetics).

I shall not deny that all this seems fanciful, or even puerile, but I wish to use the horizontal list, which places the biological sciences on the same level, as a background for more serious considerations, which it seemed best to approach by first eliminating some of the superficial emotional antagonisms that appear to be fostered by our traditional hierarchical arrangement. It will be noticed that the names of one half of the sciences are printed in heavy, the other half in lighter type. This is not for the purpose of emphasizing another evaluative distinction, that of importance and insignificance, but to call attention to the difference between the pure and mixed sciences. The former are often the older and are clearly the more independent in their general theoretical structure. Taxonomy, indeed, is quite independent, because it is the one biological science that has no theory, being merely diagnostics and classification. Modern taxonomy does, of course, assume a new significance in the light of evolutionary theory borrowed from phylogenetics, but it would probably have reached its present stage of development if that theory had never been thought of. Phylogenetics, morphology, physiology, psychology and sociology have clearly marked leading theoretical conceptions which are epitomized in the terms "history," "structure," "function," "mind" and "society," whereas the remaining biological sciences derive so much of their theory from their neighbors in the series, that they may be called mixed or blended sciences. Thus genetics combines morphology and physiology with an obvious though somewhat negativistic relation to taxonomy and phylogenetics; ethnology, or ecology as it is usually called, mixes physiology, psychology, morphology and phylogenetics; biogeography combines taxonomy, ethology, paleontology and phylogenetics; paleontology is a mixture of taxonomy, morphology, phylogenetics and ethology. In pathology the morphology, physiology, psychology and

phylogenetics of diseased organisms are combined, and anthropology may be regarded as a mixture of nearly the whole series of the biological sciences in so far as they have theoretical material applicable to man. The origin and splendid development of genetics within the past three decades suggest that other mixed sciences may arise in the future.

Each science is characterized by its theoretical constitution and this is, of course, conditioned by the peculiar interests of the investigator and the particular sector of reality to which they are directed. It is not surprising, therefore, that the sciences should be afflicted with an extraordinary number of logical oppositions, dilemmas, or contingencies between their theories. Some of the oppositions may be very persistent while others are capable of resolution or composition as soon as a higher or more synthetic theory has been excogitated to include them by a process not unlike that of the resolution of opposed statements or propositions in dialectics, on the principle that resolution is always possible between oppositions but never between contradictions.[6] Thus the formerly opposed theories of light and electricity in physics have been harmonized and the conflicts between the whole sciences of physics and chemistry are being smoothed out in recent atomic theory. A similar resolution seems to be imminent between physiology on the one hand and chemistry and physics on the other. Of course, the most acute contingency in biology is that between psychology and the other sciences and its resolution is not in sight, though some of the behaviorists are struggling to bring it about. Many less flagrant oppositions might be cited, such as that between the theory of the inheritance of acquired characters in phylogenetics and the present theories of genetics; within morphology, that between the static typology of comparative anatomy and the dynamic typology of experimental embryology; within phylogenetics, that between the monophyletic and polyphyletic theories of descent, etc. In all these cases it may yet be possible to invent more comprehensive theories that will compose the contingencies and from which the opposed theories may be deduced. The whole matter of the logical contingency of theories is very complicated, as Adolph Meyer has recently shown in a valuable but rather abstruse essay.[7] I have touched on it here, because it is illustrated by the dualism between certain ideas or orientations that have an important bearing on the biological sciences as a whole.

I return to our horizontal list which I have covered with two gray, partially overlapping areas as a rough visual indication of the distribution and dominance of these two ideas in the biological parliament. It will be seen that the



darker is concentrated in physiology and the immediately adjacent sciences, experimental morphology, genetics and pathology, and rapidly dwindles away towards the two wings. It may be taken to represent theoretical preoccupation with inframicroscopic reality. The larger area is much constricted in the center and spreads rapidly towards either end and may be taken to represent preoccupation with larger and larger microscopic and macroscopic entities. At the extreme wings these may

[6] See M. J. Adler, "Dialectic," New York and London, 1927, p. 188.

[7] A. Meyer, "Kontingenzerscheinungen an naturwissenschaftlichen Theorien," Symposion 1, 1926, p. 233–268.

be very comprehensive, as, *e.g.*, in taxonomy, with the whole existing fauna or flora or the whole biota considered as a unit, or in sociology with the whole Great Society, or the human race regarded *sub specie societatis*.

The same diagram may be used to illustrate the scope of two other more important contingent conceptions, or ideas, which have been emphasized by a whole school of German philosophers and historians, comprising Windelband, Troeltsch, Simmel, Rickert,[8] Münsterberg, Mehlis,[9] Kroner[10] and Meyer,[11] who designate them as the ideas of historism, or the idiographic and naturalism, or the nomothetic. To some of these writers they represent the two most significant directions of modern thought. Their differences are best illustrated by the sharp contrast between the investigative orientation of the historian and that of the physicist. The historian is interested in individuals and therefore in unique, more or less irrational, temporal manifestations of the real and in the values and purposes they assume, especially in their social and cultural relations. Since his investigations are confined to the past he is debarred from experiment and since he centers his attention on the qualitative, rather than on the quantitative, he can dispense with mathematics and employ verbal description, devoid of a special, technical vocabulary. He is more or less intuitive and may be said to be in search of meanings and symbolisms rather than causality, so that his conclusions are interpretations rather than explanations. The physicist, on the contrary, is not interested in the individual and unique, but in the general, or universal, quantitative and therefore measurable aspects of phenomena. He ignores the irrational, evaluative and purposive and confines himself to a purely rational explanation of the recurrent uniformities, or laws of reality, which he determines by analytical experiment and expresses in the exact language of mathematics. These schematic differences between the idiographic and nomothetic approaches to actuality have been greatly amplified in the works of the authors to whom I have referred and especially in Rickert's erudite treatise, which is now a classic. They have used the contrast to justify a dichotomy of the sciences into *Geisteswissenschaften* (history, sociology, psychology and philosophy) on the one hand, and *Realwissenschaften*, or natural sciences on the other. It is admitted, however, that biology is a hybrid in which both idiographic and nomothetic tendencies struggle for expression. Recently Kroner and Meyer have discussed the situation in this science, and Kroner has shown that the "historic" aspects of geology and cosmogony do not really fall within the idiographic scheme.

Although the general validity of the two contingent ideas has been questioned, especially by Tönnies,[12] Cassirer[13] and Höffding,[14] they do seem to divide

[8] H. Rickert, "Die Grenzen der naturwissenschaftlichen Begriffsbildung," 3. u. 4. Aufl. Tübingen, 1921.

[9] G. Mehlis, "Lehrbuch der Geschichtsphilosophie," Berlin, 1915.

[10] R. Kroner, "Zweck und Gesetz in der Biologie. Eine logische Untersuchung," Tübingen, 1913, and "Das Problem der historischen Biologie," Berlin, 1919.

[11] A. Meyer, "Logik der Morphologie im Rahmen einer Logik der gesamten Biologie," Berlin, 1926.

[12] F. Tönnies, "Gemeinschaft und Gesellschaft," 3. Aufl. 1920; see also A. Riehl, "Zur Einführung in die Philosophie der Gegenwart," 3 Aufl. Leipzig, 1908, p. 182; and P. Barth, "Die Philosophie der Geschichte als Sociologie," 1. Teil, 3 u. 4 Aufl. Leipzig, 1922, p. 32, *ff*.

[13] E. Cassirer, "Substance and Function and Einstein's Theory of Relativity." Transl. by W. C. and M. C. Swabey. Chicago and London, 1923, p. 221, *ff*.

[14] H. Höffding, "La Relativité Philosophique." Trad. par J. de Coussange. Paris, 1924, p. 135, *ff*.

the biological domain somewhat as represented in my diagram by the dark and light gray areas. Nevertheless, since biologists of all persuasions are really closer to one another than they are to the philosophers, chemists and physicists, the nomothetes have become infected with historism and the idiographers with naturalism. The language of both parties, therefore, is often so confused as to elicit from the epistemologists and theorists very disparaging remarks like those reported in the first paragraph of this paper. It is worth noting in this connection that the theory of evolution, or transformism—the only theory in the really grand manner that biology has given to the world—is obviously historistic and a creation of the idiographers. It has profoundly influenced even the philosophers and historians and is now invading atomic speculation. It is not surprising to find, therefore, that the physiologists often use such words as "organ," "function," "organism," "adaptation," "genesis," "heredity," "development," which certainly do not belong to their proper nomothetic, but to the idiographic, or historistic idiom. Of course, the physiologists might say that they use such language only when they are talking in their sleep or under the influence of anesthetics. The idiographers, on the other hand, feel that they have a perfect right to use nomothetic language, though they avoid it as a rule, not because it offends against good taste, but because it is too concise to serve as a medium for their own more exuberant lucubrations. It is only when a true philosopher like Hans Driesch enters the biological pasture that the idiographic sheep and nomothetic goats are made to realize the full iniquity of their contingencies. He informs the sheep that they are really woolly teleologists and the goats that they are nothing but hairy mechanists, and that he can make them all lie down and ruminate together if they will only permit him to bring in some of his queer creatures, the entelechies and psychoids, from the metaphysical barnyard to act as go-betweens. The metaphor is so distressingly bucolic that perhaps I had better try to express my meaning in less capricious language.

Driesch, Bergson and other vitalists were keenly aware of the dilemma that had developed between our historistic and naturalistic orientations. To Bergson it wore the guise of an opposition between intuition and intelligence, while Driesch, who was in closer touch with the biological situation, was more impressed by the old conflict between teleology and mechanism. We are now convinced that both of these popular word-realisms, the one imported into biology from philosophy, the other from Cartesian physics, are little more than fetishes. While the nomothetes among the biologists were prostrating themselves before Mechanism, some of the more bolshevistic physicists very stealthily carried it off and dropped it into the sea. Most of the physicists, of course, keep mum about the matter, but occasionally one of them may be heard to berate the nomothetes who still long for their tin deity. Thus even Professor Whitehead,[15] gentlest and most courteous of mathematician-philosophers, after referring to the various scientific idols that have lately been stolen from their worshippers, is moved to exclaim with a touch of irritation: "What is the sense of talking about a mechanical explanation when you do not know what you mean by mechanics?" And so conservative a physicist as Professor Bridgman[16] seems to imply that any of his fellow physicists who are still tempted to cry for their old image had better hurry to the con-

[15] *Loco citato*, p. 23; see also Schaxel, *l.c.*, p. 158.

[16] P. W. Bridgman, "The Logic of Modern Physics," New York, 1927.

fessional. He says: "I believe many will discover in themselves a longing for mechanical explanation which has all the tenacity of original sin. The discovery of such a desire need not occasion any particular alarm, because it is easy to see how the demand for this sort of explanation has its origin in the enormous preponderance of the mechanical in our physical experience. But nevertheless, just as the old monk struggled to subdue the flesh, so must the physicist struggle to subdue this sometimes irresistible, but perfectly unjustifiable desire." Driesch's first mistake was that of accepting the mechanistic theory at its face value. Then he went astray in construing the phenomena of regulation and adaptation as manifestations of teleology, or design. He therefore set about the conciliation of the animals in the biological pasture in the wrong manner. He should have told the goats that they were miserable sinners and the sheep that they were sentimental softies and have preserved a discreet and absolute silence in regard to the entelechies and psychoids that were quietly munching ectoplasm and other spiritual fodder in the transcendental corral.

It is well known that vitalism has many more lives than the proverbial cat and that it periodically invades and confuses biology, introducing its metaphysical entities for the purpose of resolving theoretical conflicts, just as the gods were brought down in the machine to straighten out the plots of the Greek drama. That we have again entered on a period that abhors such artifices is shown by the literature, in which references to Driesch's entelechism, the most serious and elaborate attempt ever made to provide biological *dei ex machina*, are becoming increasingly rare. The same is true of Bergson's "élan vital," which naturally played a greater rôle in philosophy. We still have on our hands, therefore, the contingency between the historistic and naturalistic ideas, and the question arises as to whether there are any means of overcoming their opposition. I believe that there are at least three recent theories, which, with some mutual adjustment, might yield a provisional synthesis, or at any rate clarify the conflict. These are the theory known as emergence, or "holism," the configuration, or "Gestalt," theory and behaviorism. The first had its origin in epistemology, the second in psychology and the third in ethology. The theory of holism, first elaborated by Alexander,[17] C. Lloyd Morgan,[18] and Smuts,[19] and recently approved by Höffding,[20] Oskar Hertwig,[21] R. B. Perry,[22] Lovejoy,[23] Bertalanffy,[24] Ritter and Bailey,[25] and others, starts from the consideration that the properties of a whole, as distinguished from a mere aggregate, sum or collection, though determined by the interrelations and interactions of the parts, are nevertheless novel and, except after previous knowledge of the mode of composition of the parts, unpredictable.

[17] S. Alexander, "Space, Time and Deity," 2 vols., London and New York, 1920.

[18] C. L. Morgan, "Emergent Evolution," London and New York, 1926.

[19] J. C. Smuts, "Holism and Evolution," London and New York, 1926.

[20] *Loco citato*, p. 42, 160.

[21] O. Hertwig, "Das Werden der Organismen," 3. Aufl. Jena, 1922.

[22] R. B. Perry, "General Theory of Value," New York and London, 1926.

[23] A. O. Lovejoy, "The Meaning of Emergence and its Modes," *Journ. Philos.*, Studies 2, pp. 167–189.

[24] *Loco citato.*

[25] W. E. Ritter and E. W. Bailey, "The Organismal Conception, Its Place in Science and its Bearing on Philosophy," Univ. Calif. Publ. Zool., 31, 1926, p. 307–358. For additional bibliographic references to emergence see my booklet, "Emergent Evolution and the Development of Societies," N. Y., W. W. Norton & Co., 1928. Professor Lovejoy has called my attention to an early, lucid statement on emergence in Maudsley's "Body and Will," 1884, p. 132.

That this "creative synthesis" is an empirical fact is shown by all chemical compounds and may be generalized to include all wholes, atomic, molecular, colloidal, cellular, organismal, psychical or social. There seems to be no good reason why we should not throw in also such astronomical wholes as the suns, planets, comets, solar system and galaxies for good measure, though we may have to stop this side of the universe because we can never know whether it is an emergent, even if it should prove to be a whole.

In all these existants we behold an inexplicable "social" tendency for wholes to combine and cooperate with wholes to form wholes of higher orders, or "levels," with new emergent properties. It appears to follow that at each level laws become operative which can not be formulated for emergents of lower levels, though the converse is not necessarily true. Hence the causes, or uniform functional relationships with which the biologist *sens. str.*, the psychologist and sociologist are concerned, differ from those of the physicist and chemist, though the physicochemical laws are not annulled even in such singular emergents as the organisms. All this is such a commonplace that its significance was overlooked till quite recently. The novelty stressed by the writers who have expanded this commonplace of emergence into a theory of creative evolution is evidenced by the psychical shock, or feeling of surprise which we experience when confronted with the individual emergent.

The Gestaltist, or configurationist, is also dealing with wholes, but he is more interested in their peculiar irreducibility as patterns either in space or in time than in their novelty. As illustrations he points to such wholes as are represented by identical designs in different colors on a uniform background, or the same melody played in different keys. In these cases the configurations must be due to the interrelations of their component parts, because these are very different in the same configurations. Behaviorism, both in its general, ethological form and in the radical form which it has been given by Watson, is also concerned with wholes, *i.e.*, with the action-patterns of the whole organism in response to its environment. But it is not so much the novelty or the configuration of this response *per se* as its regulative and adaptive character that interests the behaviorist. No recent tendency has been so successful as behaviorism, since it has affected the attitude of investigators in nearly every one of the biological sciences. The physiologist, pathologist, psychologist, anthropologist and sociologist have all been profoundly influenced, and even students of paleontology and phylogenetics are now adopting the behaviorist's point of view.[26]

Emergence, configuration and behaviorism are so similar that we may regard them as so many partial aspects of the single conception which has been called "organicism." The individual organisms, which constitute the only materials of biology, are certainly very peculiar emergents. They may, of course, be described as spaciotemporal events or as equilibrate systems but such descriptions seem singularly depauperate to the biologist, who prefers to regard them as very highly integrated, organized wholes endowed not only with the marvelous capacities of growth, development and reproduction but also of accumulating and registering the significant results of their own adaptive

[26] See in this connection H. Karny, "Die Methoden der phylogenetischen (stammesgeschichtlichen) Forschung," in Abderhalden's "Handbuch der biologischen Arbeitsmethoden," Abt. 9, 1925, p. 211–500, 51 figs., and B. Dürken and H. Salfeld, "Die Phylogenese. Fragestellungen zu ihrer exakten Erforschung," Berlin, 1921.

experience and of that of their ancestors over enormous periods of time and of deploying at least a distorted epitome of these results in their successive generations. They are, indeed, historical beings, as Boveri[27] maintained. The investigative orientation and methods of the historistic biologist as such, therefore, required no justification.

The peculiarities of organisms are surely sufficiently extraordinary to make them the objects of an independent, unitary group of sciences, biology, but all recent researches have shown that they are not sufficient to warrant appeals to mystical "organizatory factors," "instincts," "souls" and "social minds" to account for them. In as much as the novel organic emergents are due to the interaction of their parts it is necessary to investigate these parts and their interrelations if we are to have even a partial explanation of the whole which they constitute. Hence the nomothetic biologist is also thoroughly justified in his analytic physicochemical attitude and procedure. Regarding things as wholes, no matter how much aesthetic satisfaction or mental repose one may derive from their contemplation, is not scientific explanation. I conclude, therefore, that there is no conflict between the idiographers and the nomothetes among the biologists *sensu stricto*; they are merely working on two different levels, the physicochemical and the organismal. But organisms have also developed two other levels, those of mind and society, and it is the intrusive theories of their devotees, the psychologists, sociologists and philosophers, that disturb the harmony of the biological flock. Only those biological historists, therefore, who affect these theories, should be shorn of some of their wool to make them look more like goats. I allude, of course, to such lanuginous conceptions as "individuality," "value," "purpose" and "potentiality."

Theoretical conceptions have instrumental significance only on the phenomenal level to which they belong and become little more than word-fetishes when employed as explanations at other levels. This is obvious when philosophical, psychological and sociological notions like those just mentioned are carried down to the organismal and physicochemical levels. For example, individuality, in the sense of uniqueness, loses much of its mystery in biology since it is seen to increase at each higher emergent level as a function of the increasing multiplicity, interaction and integration of the parts in the whole, so that an atom will naturally have very little, an organism much more and a human personality a great deal of uniqueness. The irrationality and indefinability of the individual, which have such a mesmeric effect on the historists of the Rickert school and on many philosophers, are really aspects of the emergent as a novelty. In another sense, that of temporal and spacial persistence, individuality is implied in the whole as an integration or organization of parts. Some writers, notably Roux and more recently Whitehead[28] and Höffding,[29] if I understand them correctly, regard mere persistence or survival as the fundamental peculiarity of "value," but the petering out during the past seventy years of the theory of the survival of the fittest, in which this conception of value is implicit, shows that it is far too vague or philosophical to be of any use to the biologist. This was to be expected, because the theory of the survival of the fittest, or natural selection, really came to us from two sociologists of the old evaluative school, Herbert Spencer and Malthus. Of course, the ever-increasing tendency to

[27] T. Boveri, "Die Organismen als historische Wesen," Festrede 320. jähr. Bestehens Univ. Würzburg, 1906, 33 pp.

[28] *Loco citato.*

[29] *Loco citato.*

purge the biological sciences, including psychology and the new sociology, of all "values," does not imply that these may not be extremely significant in such purely hominstic sciences and pseudo-sciences as aesthetics, logic, ethics, economics, history, metaphysics and theology.

Potentiality, or possibility, is another philosophical notion that could hardly fail to be taken over by the historistic biologists when they began to study the ontogenetic development of organisms. It has persisted, under various disguises, since Aristotle—among the scholastics as the "virtues" or "occult qualities"; later as "preformation," or "evolution," in the old sense, and more recently as the "germplasm" in theories of Weismann and his school. Here the notion was elaborated in such detail that it soon revealed its true nature—the passing off of the photograph of a problem as its explanation. When experimental embryology got under way there was still much talk of "prospective potencies," or possibilities, but the emptiness of these conceptions soon became apparent, and the words "predetermination" or "Anlagen" were substituted. In this case we again see the gradual supersession of a misplaced philosophical by a useful, though not very precise, scientific concept. One often has the impression, however, that the dormitive virtues which Molière satirized are still soporific, not only in the literature of genetics but also in that of comparative psychology where they are called "instincts." In the meantime the dialecticians inform us that the realm of possibility is the peculiar and exclusive province of the philosophers, whereas the proper province of science is actuality. If I understand Adler correctly, the realm of possibility is so inexhaustible, that the philosophers can keep up disputation within its confines till the end of space-time and then start all over again. We should, therefore, generously hand over to them all the biological possibility we can collect and felicitate them on the prospective potency of their useful occupation.

Purpose, in the sense of design, teleology, or "Zielstrebigkeit" will probably be found to be quite as sterile a conception as possibility when the biologist succeeds in clarifying the very intricate phenomena which he designates as "adaptations," "coaptations," "regulations" and "restitutions." That the notion of design is often merely a misinterpretation of emergence is suggested by Professor R. B. Perry[30] when he says: "If one speaks of the structure and composition of a whole, as the 'means,' and the peculiar synthetic properties as the 'end,' one naturally supposes that the one 'seeks' the other; or exists and acts 'for the sake of' it; or that the total arrangement has been 'designed'; whereas no such thing is in the least implied." Equally finalistic and reprehensible is the statement, not infrequently encountered even in organicist writings, that the "whole determines the relations of its parts," since this, too, seems to imply—if, indeed, it implies anything—that the end determines the means. The discussion could be greatly prolonged, but perhaps I have sufficiently stressed the inefficacy of theoretical concepts when transferred from higher to lower levels where at best they merely introduce confusion. A very different picture is presented by the theoretical structures that have arisen naturally from the manipulation of the empirical data in any particular science and therefore belong, so to speak, to its own universe of discourse. I allude to such conceptions as the "species," or "taxon" in taxonomy; the "lineage," or "phylon" in phylogenetics; Waagen's "mutations" in paleontol-

[30] *Loco citato*, p. 153.

ogy; "age and area" in biogeography; the "type," or "character" in morphology; the "gene" in genetics; the "reflex-arc" in physiology; the "biocoenose" in ethology; the "abnormal" or "atypical" in pathology; "race" in anthropology; the "complex" in psychology and the "socius" in sociology. Most or all of these are really fictions, or "as-ifs," in Vaihinger's sense, but their practical, heuristic and synthetic usefulness is beyond dispute.[31]

Organicism, conceived as emergence, seems to me to resolve the opposition between historism and naturalism, at least in the forms assumed by these ideas in biology. Emergence can not offend the physiologist, because there is nothing mysterious or unscientific about it. The same is true of the configurationist's formulation of organicism, since configurations, or "Gestalten" occur also among purely physical phenomena, as Koehler has shown. And the radical behaviorists are not only outspoken holists, but adopt a decidedly hostile attitude towards many of the philosophical "residues" in biology, like those I have been considering. On the other hand, the theory of emergence must be welcome to the historistic biologist, because it releases him from the Procrustean bed of mechanism and enables him to express freely the firm conviction which he has always shared with the historians and philosophers, that evolution, both in its progressive and retrogressive manifestations, is a continual generation of novelties, an unceasing process of creation.

The upshot of this rather involved discussion would seem to be that we can clarify and tone down the oppositions among theories by rejecting a lot of adventitious and often mystical notions that have been foisted upon the biological sciences by historians and philosophers, but that certain oppositions will remain for the simple reason that organisms embrace no less than four disparate levels of emergence, the physicochemical, the organismal, the mental and the social. Hence, till the advent of a few Supereinsteins, theoretical biology must stand as a combination of oppositions—a *compositio oppositorum*. This is not a "Zersplitterung," however, as conceived by the critics, presaging decomposition or dissolution, but a sign of vigor and vital unity, like that of the healthy organism, in which what we call life is intrinsically the antagonistic synergy of its component parts. The hopefulness of the present biological situation is even more apparent in the attitude of the creators of the biological theories, the biologists themselves. So impressive is the amount and quality of accomplishment in every one of the biological sciences that not even the narrowest specialist can now adopt the unsympathetic attitude so prevalent among eminent investigators of the past generation, for the veriest tyro soon becomes aware of his indebtedness to his fellow investigators in the most remote biological sciences. Even those tiresome old ladies, the taxonomists, are regarded as rather helpful by petulant infant geneticists, if only as donors of the India-rubber species on which they cut their milk teeth. But there is among biologists a stronger bond than that of mutual gratitude for services received and that is their common love of the living world and their desire to arouse such a love in others. The great museum in which we are meeting is one of the glorious manifestations of that feeling. There is one of Augustine's aphorisms—*res tantum cognoscitur, quantum deligitur*, a thing is understood to the degree that it is loved—which, with some interpretative manipulation, may serve to

[31] H. Vaihinger, "Die Philosophie des Als Ob," 9–10 Aufl. Leipzig, 1927. For a discussion of the main fictions in biology see J. Schultz, "Die Grundfiktionen der Biologie," Berlin, 1920.

convey my meaning. Of course, Augustine would have been shocked or perhaps outraged had he deemed it possible that a mere worldly biologist could tamper with one of his most edifying remarks. From the context we may infer that the saint used "diligitur" in the sense of "contemplative or devotional love." I wish to interpret it to mean something like "investigative love." These words, unfortunately, can be construed in the sense of "perverse" or "morbid" curiosity, which might horrify or even infuriate not only Augustine but all the saints in the calendar. I hasten to state, therefore, in conclusion, that I am using the words "investigative love" with a strictly proper meaning and as the best I can find to designate that union of the historistic and naturalistic interests which seems to inspire an ever-increasing number of our biologists and promises the fullest ultimate understanding of animate nature.

MIGRATIONS OF ASIATIC RACES AND CULTURES TO NORTH AMERICA[1]

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EVER since we have learned to look at the development of man as a historical process the interest of the student has been directed toward the discovery of our ancestry, of the place of the first appearance of man on our globe and of the history of his migration over the continents. A special aspect of this problem is the history of the appearance of man in America.

All the evidence that we possess up to this time leads us to believe that man did not develop from lower, ancestral forms on the western hemisphere. All his closest relations among the higher mammals live and lived in early geological periods in the Old World; in Europe, Africa and Asia. No forms from which man can be descended have ever been found in America. A single tooth, found in Nebraska, which was once believed to have possibly belonged to a higher ape, has proved to be that of a peccari.

It seems, therefore, reasonable to assume that man developed in the Old World and came to America later. The time of his immigration can not yet be fixed with any degree of certainty, but some limitations may be established. Since the end of the Tertiary the Old World and the New have been separated by the Atlantic Ocean so that the immigration of living beings in this direction has been impossible ever since the land connection in the far north disappeared. If Tertiary man existed in Europe, as is claimed by some investigators, he might have come to America over the old land bridge. We have, however, no evidence whatever of the presence of man in the New World at this period.

Although negative evidence, in this case the lack of finds, is never conclusive, there are other reasons that induce us to conclude that man did not reach America by this route and at this early period. The earliest remains of man found in Europe differ from modern races. They are rather predecessors of modern man, although not necessarily his immediate ancestors. The American race, on the other hand, is morphologically closely allied to the Mongolid race of Asia. Notwithstanding the great differentiation of American Indian types in North America and South America, they bear throughout a decided resemblance to the East Asiatic type and differ from all other races. Even the earliest remains of man found on the western hemisphere share these characteristics. We must, therefore, assume that these two groups had a common origin. The differentiation of the Mongolid race must have occurred before man came to America.

Just when this differentiation developed is still an open question. If it is permissible to judge by analogy, we might place these events in the later Paleolithic period, contemporaneous with the appearance of the Cro-Magnon type. It is, however, quite possible that the origin of this race may date farther back and that it may have appeared in Europe towards the later part of the long Paleolithic period. The determination of the period in which the differentiation of the negroid and Mongolid races occurred will give us the earliest date of the arrival of man in America.

[1] Address before a joint meeting of the American Association for the Advancement of Science and the American Anthropological Association, New York, December 29, 1928.

Positive evidence is still lacking of man's arrival before the end of the great glaciation that separated America from the Old World. Even the most carefully investigated finds that have been made admit of the explanation that they belong to the early post-pleistocene, to a period when the great glaciers had retreated northward. They show, however, that the technical skill of man in the early post-pleistocene was far advanced. The forms are not distinguishable in technical character from those of the modern Indian, before the advent of the Europeans. There is an apparent contradiction between the paleontological evidence and the types of implements found. The animals with which the earliest human remains are associated, are in part extinct and fossilized. Their geological position suggests that these forms may have become extinct much later than is usually assumed.

The final determination of the problem of the first arrival of man on our continent will be solved by geologists. It is a geological problem requiring the determination of the period in which the strata were deposited that contain the remains of animals, of man and of his handiwork. The paleontologist and anthropologist must accept the findings of the geologist and they must shape their conclusions according to the chronology established by the geologist. Unfortunately, this fact is not yet sufficiently recognized and too great weight is given to the types of animal, man and artifacts found. Efforts must be made to ascertain with the greatest accuracy, the geological age. Apparent contradictions between the geological and paleontological or anthropological evidence may lead to a reexamination of the geological conditions, but the decision must be made by the geologist. The closest cooperation between geologists, paleontologists and anthropologists must, therefore, be demanded.

A consideration of the actual conditions on the American continent makes us inclined to consider the post-pleistocene period as rather short for the development of the differentiation in types and languages that has occurred.

If it is true that man came here by way of Siberia and the extreme northwestern part of our continent, at a time when a wide land-bridge existed in place of Bering Sea, and gradually spread over North and South America, he was compelled to become acclimated to the tropics, and in his further migrations southward, to the inhospitable climate of the extreme southern part of South America. The American Indians of various areas differ considerably among themselves and there must have been sufficient time for the development of distinct types. The languages differ enormously in general structure and we must allow time for their development. The fundamental differences in bodily form, language and culture must always be borne in mind and should not be slurred over.

It is not likely that the migration of man into America occurred just once. It may have been a continuous process extending over a long period and bringing different types and different languages into our continent. If we were to assume that the various types and languages represent, unchanged, different waves of migration, we should merely add a new hypothesis to the others, for there is no evidence that the American types existed at an earlier time in Asia.

On account of these considerations it seemed appropriate to consider the whole problem from another angle. Instead of asking what has happened in earliest times, we might rather investigate the relations that exist at present between the two continents and inquire what historical inferences may be drawn from them. It was this problem which I presented in 1896 to Morris K. Jesup, president of the American Museum of Natural History, and which led to the

organization of the Jesup North Pacific Expedition, which was liberally financed by Mr. Jesup and the direction of which was entrusted to me.

The problem before us was primarily an investigation of the coast region of the North Pacific Ocean for the purpose of determining the anthropological interrelation between America and Asia. This necessitated a careful investigation of the anthropological types, languages and cultures of the whole area, together with an attempt to ascertain their development during early times by means of an archeological inquiry.

It was known from previous investigations that the east Asiatic type and the Northwest American type show close resemblance, so much so that in some individuals it might be doubtful to which continental area they belonged; but the local types of the whole district were not well known. It was one of our tasks to obtain a better insight into the relations of native types. In the extreme north we find the Eskimo of Alaska. The eastern Eskimo present a very characteristic and easily recognized bodily form which sets them off sharply from their southern Indian neighbors. In Alaska these features are not so pronounced and relationships appear to both the Indian and East Asiatic forms. Still, the people are most closely related to the Eskimo type. On the other hand the types of the coast of southern Alaska and of the adjoining interior do not seem to me to an equal degree distinct from those of southern Siberia. The similarity of the crania of the two groups has been shown by Dr. Dina Jochelson-Brodsky. They differ, however, in facial form. Later on the observations of Russian investigators were corroborated by Dr. Hrdlička. His claim that the difference in facial form is secondary, due to environmental conditions, can not be claimed to be more than a hypothesis. A comparison of American and Siberian forms is made difficult by the extended migrations that have occurred in Siberia, where Turkish and Tungus tribes have, to a great extent, superseded the ancient native people.

The two outstanding problems are, therefore, the examination of those areas in which those types of the two continents occur that are most alike, and the other one how to interpret the distribution of dissimilar types. So far as we can see at present, the Eskimo and perhaps also the Arctic Siberians separate two types that show a certain degree of similarity. This may be due either to a parallel development or to an older historic relation. Evidently the solution of this question can be given only by a widely extended investigation of the prehistoric remains of this area, an expensive and laborious undertaking that lay outside of the possibilities of the Jesup Expedition. Unfortunately up to this time material from Alaska has been collected more with a view of accumulating masses of objects rather than of obtaining a carefully observed stratigraphically determined series. In recent investigations Jenness and Collins seem to have devoted greater care to strata and sequence. The problem to be decided is, whether the Eskimo type is the oldest one in this area, or whether it is intrusive and overlies more ancient types similar to those of the Northwest coast. By this investigation we may also determine whether the Eskimo intrusion came from the West or from the East. This must remain an open question until careful and extensive observations on the ancient remains of the whole area, extending from the Amur River northward and along both coasts of Bering Sea, will be undertaken. This is at present one of the most urgent needs for the solution of the problem of the interrelation between the early populations of America and Asia.

The relation between Asia and America may also be investigated by an examination of the modern cultural forms.

The work of the Jesup expedition was devoted particularly to this problem.

First of all it seemed necessary to inquire into the possibility of linguistic relationships. Siberia and the Pacific Coast of America belong to those parts of the world in which we still find a great number of apparently unrelated languages, each spoken in a limited area. In Siberia the older conditions have been disturbed by the influx of Tungus and Turkish tribes. According to recent observations by Professor Bogoras, one of the valued members of the Jesup Expedition, many of the small tribes that speak now Turkish dialects must be considered assimilated tribes. What language they may have spoken in early times can not now be ascertained. The isolated tribes of Siberia are generally designated by the term Palaeasiatics, and Professor Bogoras and Mr. Jochelson find their similarity to the American tribes so striking that they speak of them as Americanoid.

On account of the fundamental structural differenees of American languages among themselves and similar differences of the Siberian languages among themselves, it is impossible to trace the origin of American languages to Siberia or those of Siberia to America. The eastern Siberian languages have certain features in common with other Asiatic languages, for instance, the importance in their structure of vocalic harmony, while in regard to other traits such as the incorporation of the nominal object in the verbal complex they resemble certain American types.

A comparison between Chukchee, a language of the extreme eastern part of Siberia, and of the Eskimo reveals a peculiar relation. While the fundamental traits of the structure of these languages are quite diverse, a number of peculiar features are common to both. Some of these are purely formative elements, like the suffix *-t* which forms the plural. Others are rather psychological categories that are expressed in both languages, although they are absent among the neighboring tribes. To this group belong the similar development of verbal modes, and the peculiar difference in the treatment of the subject of transitive and intransitive verbs, a feature which occurs in many American languages. I believe we may infer from this ancient cultural contact so close that it has resulted in the contamination of linguistic structure.

More conclusive results have been obtained through a study of other cultural traits of the tribes of this area. A careful analysis has led us to recognize the fundamental unity of the culture of the circumpolar area of both the New and the Old Worlds.

A single problem of unusual interest may be mentioned first. The type of man found in the deposits of the late Magdalenian resembles the modern Eskimo and the implements of that period are not unlike those that characterize the modern Eskimo culture. On this basis the conjecture has been made by Boyd-Dawkins that with the gradual retirement of the Tundra northeastward, Magdalenian man, the so-called Cro-Magnon race, followed the reindeer northeastward and thus travelled through Siberia and finally reached the American continent, so that our Eskimo would have to be considered descendants of the Cro-Magnon race. While we may acknowledge the attractiveness of such a hypothesis, it is hardly acceptable at this moment; not so much because there are important differences between the two human types and the two cultures, for these might have developed in a long span of time, as for the reason that there is no archeological evidence connecting these remote areas. It would be necessary to show that the Cro-Magnon type and his culture left remains in the intervening parts of Asia. The few prehistoric sites in Siberia which have come to our knowledge, particularly through

the efforts of Petri, do not give us any clue that would corroborate the hypothesis. The similarity between Magdalenian and Eskimo is, however, great enough to deserve further study, which must be carried on in Siberia and eastern Europe. The most recent investigation of Eskimo culture over the whole district from Alaska to Davis Strait has proved that the modern Eskimo culture has almost everywhere degenerated from an older type which was technically, and in art forms, far superior to that of the present time. The similarity between Magdalenian and Eskimo must, therefore, be based more rigidly on a comparative study of ancient Eskimo culture rather than on that of modern times.

The characteristics of the circumpolar culture are only in part explained by the similarity of geographical environment. The climate does not permit agriculture and all the people rely essentially upon animal food, fish, sea mammals and land animals. The domestication of the dog is known not only to the circumpolar region but is well-nigh universal. It is, however, characteristic of this region alone that the dog is used as a draft animal. It is not unlikely that the dog cart which has been used up to the present in northern Europe is a survival of this use of the dog. In Asia and Arctic America the dog is used as a draft animal in connection with a sledge. In America its use has spread southward from the Arctic region, but the Indian tribes of the Plains use it in a peculiar manner. Instead of the sledge or toboggan, they use a frame resting on two poles which are tied to each side of the dog and which are dragged over the ground. This contrivance, the so-called travois, was used both in summer and winter.

Another characteristic trait of the circumpolar region is the use of birchbark for making vessels and canoes and for building houses. The Indian birchbark wigwam is well known. The construction of the Siberian tent is, in principle, the same. A frame-work of poles is erected and covered over with sheets of birchbark. The bark canoes are also of similar structure.

The possibility of navigation was presumably discovered by the observation of floating logs, floating grass, and by the buoyancy of vessels. We do not know the sequence of the inventions which led to the art of navigation, but it seems plausible that rafts were among the forms first used. In neolithic times in Europe, dugouts were made. Sometimes these were strengthened by ribs left standing when the trunk was hollowed out. It would seem that this invention was easier than that of the canoe consisting of a framework of ribs covered with birchbark or hide, a much more complex structure. In northern Denmark golden votive offerings were found that seem to represent a framework of ribs covered with skins. Caesar described boats of the same kind, as used by the natives of England. Even at the present time the coracle is used in Wales. Boats of this type of structure, covered in the southern regions with bark, in those parts of the country where wood is not available with skins, are characteristic of the whole circumpolar area. In some regions striking similarities are found, thus the general structure of the birchbark canoe of the Amur River and that of the Kutenai of British Columbia are very much alike.

It might be said that the use of skins and bark for covering framework is dictated by the availability of these materials, but this point of view is hardly tenable when we consider also the similarity of the birchbark vessels which are used on both continents. Baskets and vessels of various kinds are formed by cutting and folding birchbark in appropriate ways and many of the ideas of treatment are practically identical. The strengthening of the rim, and the decoration of the sides are characteristic for

Siberia and for America, but they do not seem to occur in other parts of the world.

Attention may also be called to the similarity in the construction of the houses. Particularly in northeastern Siberia and among the Eskimos we find a subterranean house. A shallow pit is dug and a roof erected over it with a smoke hole in the center, which at the same time serves as an entrance to the house, a ladder being placed on the floor and leading up to the smoke hole. In some cases the entrance is through a tunnel at the side. This very characteristic structure has been observed, not only in the Arctic area where it might be explained by the necessity of the climate, but it has also been found much farther to the south. All through the northern part of the great plateaus of the American west we find subterranean houses of this structure. They occur in California and may even be recognized in the underground ceremonial houses of the Pueblos, and in their ancient dwelling houses with entrance through the roof. Farther south in Asia and also on the Pacific Coast of British Columbia, this type of house is not found, but it is remarkable that in mythological tales and in certain sacred ceremonies, the entrance to the wooden houses of these areas is not through a door. The supernatural beings or novices disappear and reappear through the smoke hole. This leads us to think that perhaps in earlier times similar dwellings, with entrance through the roof, may have existed here.

Common to Siberia and America is also the characteristic flat drum, consisting of a hoop covered by a single head, sometimes with a handle consisting of crossed thongs or wire or similar material. In practically all other regions where drums with a single head occur, the shell is high, as for instance in the large drums of Africa. The only other form similar to the American and Siberian drum is the tambourine, which seems to be confined to the Mediterranean and to southern Asia. The tambourine is much smaller and is characterized by the additional jingles.

I do not feel convinced that the use of tailored fur clothing and the methods of fishing can be added as a proof of ancient, historical relationship, because they are so much dependent upon climatic and geographic conditions.

Another feature common to the northwestern part of America and to Asia is the use of slat armor, consisting of cuirasses and other protective devices made of rods or slats, of wood, bone or ivory, securely lashed together. If this type of armor should have developed from Chinese and Japanese patterns it would be proof of an early, long-continued cultural influence that extended northward and southeastward. Of similar character is the use of the sinew-backed bow which is widely used in the Old World and occurs in an extensive area of Northwest America.

Similarities in religious ceremonials, beliefs and traditions prove an intimate relation between Asia and America. Quite recently Dr. Hallowell has published a detailed study of the bear ceremonial in the Old and New Worlds and proved its wide distribution over the whole extent of the circumpolar area and the adjoining districts farther to the south. It is hardly admissible to assume that the cult of the bear has developed independently all over this country on account of the fear inspired by this animal, for form and content are too much alike. At the same time these particular ceremonials are not found in regard to other dangerous animals.

Attention might also be called to the peculiar use of wood-shavings, grasses, and shredded bark as religious symbols which characterize the ceremonials of the Ainu, Koryak, Chukchee, and of the coast tribes of British Columbia and southern Alaska.

Strong proof of cultural relations between Asia and America is found in the folk tradition of the various tribes. In this field the isolation of the Eskimo is

particularly striking. In contrast to most other tribes the Eskimo tradtiion deals much more with human society than with animals, and their more important animal tales can be proved to be of Indian origin. But at the same time the Eskimo are exceedingly tenacious in form and content of their tradition. The same formulas occur in tales from East Greenland and in those from both sides of Bering Strait. The striking differences between Eskimo lore and that of their Indian and Asiatic neighbors, is one of the arguments that speak for a late intrusion of the Eskimo into Alaska. Mr. Jochelson and Professor Bogoras have made detailed comparisons of American Indian and Siberian folklore and they have proved that many elements are common to both. The number of correspondences is so large that independent origin is excluded. If we should judge by the elaboration of the various themes, we might conclude that they have their home in America and were carried to Asia, but such an argument is of doubtful validity, because tales may have degenerated in one area while there may have been a prolific development in another.

A number of themes prove clearly the importation of Old World lore into America. One of the striking examples is the famous story of the magic flight, which is spread in the Old World from Morocco to Bering Strait, and it is known in closely allied form in America all along the Arctic coasts, on the north Pacific Coast, and inland as far as the Mississippi Valley. This tale has been embodied in the most sacred traditions of British Columbia and for this reason it may be assumed that it has been known there for a long time.

Mr. Jochelson has made a statistical study of the episodes of Koryak folklore in comparison with those of the Old World and of America, and he has found that among 122 episodes, 84 per cent. are common to Asia and America exeluding the Eskimo; 24 per cent. to Asia and the Eskimo; and that only 20 per cent. are repeated in other parts of the Old World.

The intimate relationship of North Asiatic and Northwestern American culture has been fully established by these researches. A study of American material has also shown that the cultural traits that may be traced to the Old World, extend in America south and eastward to the western plains and the Mississippi Valley, weakening the farther away we move from the Arctic and from Alaska.

Cultural relations of the kind here discussed do not develop suddenly, but are the result of long-continued contact.

In order to understand the relations between America and Asia clearly it is also necessary to investigate the fundamental differences between Siberian and American culture, differences that might indicate a lack of mutual influences.

The fundamental traits of American culture are so distinct from those of the Old World that they corroborate our view of a very early immigration of man into our continent. American agriculture is based on the cultivation of American plants; Indian corn, squashes and beans are native American plants and there is no trace of the use of any of the Old World plants. The Americans had no domesticated animals excepting the dog which had an almost universal distribution, the llama in the Andean highlands and the turkey.

There are also striking differences in the general character of political organization and religious belief. Weakness of administrative function, almost complete absence of judicial procedure characterize American political organization. Absence of a belief in obsession and a different attitude towards shamanism may be observed. Among the American Indians shamanistic power is generally sought, rather than involuntarily imposed. Among the tribes of Siberia it is an unwelcome gift of supernatural power that is resisted.

One of the most striking features is the absence of domesticated reindeer in America while they are used by all the Siberian tribes. For many centuries the Alaskan Eskimo must have been familiar with the domesticated reindeer, still they have never been inclined to take up its domestication. It may well be that the extensive use of the dog was a hindrance, for it requires special training to teach the dogs not to attack the reindeer. The failure to adopt reindeer breeding may also be due to the wealth of sea-life which, under normal conditions, gave to the Eskimo ample supplies with less arduous work than that required for reindeer breeding. The general conditions of reindeer breeding indicate that the art of domestication is least developed among the Chukchee and it seems plausible that the art sprang up in western Siberia and gradually reached the most eastern part of Asia. There is every probability that the tribes of Siberia were by origin hunters and fishermen and that particularly the Chukchee participated in this mode of life. As a matter of fact a large portion of the Chukchee have no reindeer even at the present time, but live as maritime hunters in permanent villages. It is also well worth remarking that the clumsy tent of the nomadic Chukchee is, in its general plan, analogous to the underground house of the maritime Chukchee, so that survivals of older sea hunting life may be recognized even now among this tribe.

It is necessary to look at the whole problem from another angle. The study of American inventions, customs and beliefs shows that a gap exists between the cultures of the central parts of both Americas and the extreme northwest and the extreme south of South America. The advanced civilizations of Central America and of the Andean Plateaus have influenced the greater part of our continent directly and indirectly, and the inventions, customs and beliefs of the more primitive tribes have been overlaid by cultural traits which have spread northward and southward from Central America. The older forms of American culture survive in the marginal areas on the northwest coast and independent development has occurred into which all the tribes that migrated from the interior to the coast have been drawn. The greater part of the continent is, therefore, influenced by a high culture which has developed independently of the Old World and it is, therefore, but natural that closer relations between the two continents will be found in the northwestern part, which is not only nearest to Asia but where also the older traits have not been obscured.

A last problem remains to be solved. If we acknowledge that cultural relations exist between Asia and America, the question should be answered whether the origin of these customs must necessarily be looked for in the Old World. I doubt whether it will be possible to give a categorical answer to this problem, but I incline to the opinion that the general history may have been the following. At an early time the Mongolid races migrated in a number of waves into the American continent and were gradually driven southward by the inclemency of the Arctic climate. Later on when the climate became more temperate, man settled again in the more northern districts and an eastern and western wave turned northward. The outposts of the eastern wave may have been the Eskimo, while the western wave moved across Bering Strait and back into Siberia where they later on amalgamated with Old World tribes which also migrated northward when Siberia became habitable.

We are still far from being able to give a categorical answer to these problems but we may hope that continued researches, and particularly archeological researches, in the Arctic may enable us to clear up the later phases of the migrations of the aborigines.

HEREDITY AND NATURAL RESISTANCE TO DISEASE[1]

By W. V. LAMBERT

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AN animal's development and reaction to various influences throughout its life are governed by two forces, its constitutional or inherited capacities and its environment. Neither force is independent of the other, and to reach the highest plane of development or usefulness an animal must not only be surrounded by a fit environment but it must also be equipped with a good heredity.

In relation to disease the item of constitutional fitness has been largely overlooked. Previous to Pasteur's discovery of the rôle of microorganisms as the causative agents of many diseases this concept was quite generally recognized as an important one by the medical fraternity. Following his discovery, however, the idea was pretty generally forgotten in the mad rush to discover the causative agents of each disease and in developing methods for suppressing and combating them, such as the production of vaccines and immune sera. And in many cases, as typhoid fever, rabies and swine cholera, the results have been remarkable.

In many diseases, however, no successful methods of control have been developed. This fact has led a number of workers, in genetics primarily, to undertake another possible solution of the problem, namely the production of disease-resistant strains. In the plant kingdom this method has been used extensively. As examples, strains of wheat and oats now exist that are resistant to certain forms of rust and smut, beans that are resistant to the fungus disease, anthracnose, are now grown commercially, and in cabbage selections resistant to yellows are in use.

In animals much empirical evidence exists relating to this subject. It has long been recognized that much variation in resistance to bacterial diseases exists in any group of animals. In an epidemic many individuals develop an acute form of the disease, others a mild form, while still others resist it entirely. Some of this difference undoubtedly is due to environment, but not all, for under the same environment and with equally good physical fitness the same facts are observed.

Species, racial and familial differences in resistance to disease are well known. For instance, diseases common to the rat are non-pathogenic for mice, and Texas fever, a common and fatal disease for domestic cattle in tropical and subtropical countries, is not pathogenic for the zebu. Another instance frequently cited is the high degree of immunity exhibited toward anthrax by the Algerian sheep, a disease very fatal for other breeds. In man, also, racial differences have been freely observed. It is a well-known fact that when diseases common to civilized races are introduced into uncivilized or isolated regions, where these diseases have not been present, the mortality resulting among such people is often appalling. The death rate among the American Indians following the introduction of smallpox and measles is a well-known example of this. Much other evidence of a less clear-cut nature also exists. It

[1] Paper No. 26 from the Department of Genetics, Iowa State College.

is generally considered that the negro is more susceptible to tuberculosis than the white man. Much evidence, largely statistical in nature, has been presented to show that susceptibility to tuberculosis is an inherited trait. Its incidence is significantly greater in certain families so as to leave no doubt that a weakness or inherent susceptibility toward this diathesis is an integral part of the germplasm of those families. It must be emphasized here that it is not the disease itself that is inherited, but that there is some constitutional weakness which is inherited that makes certain individuals more prone than others to infection with the tubercular bacillus.

Experimental evidence for the inheritance of resistance to disease in the laboratory mammals is not abundant. While numerous observations concerning the great variability in resistance to disease are on record, few critical attempts have been made to determine how much of this variability was due to environment and how much was inherent within the individual. Within the last few years, however, experimental results have definitely shown that it is possible by selection to produce strains of animals having a higher degree of resistance to infection with a specific bacterial disease than that possessed by the general population. This has been demonstrated in several species and for such diverse diseases as mouse typhoid, bacillary white diarrhea in chickens, fowl typhoid and for a disease among rats induced by inoculation. It has, likewise, been demonstrated that inbred lines exhibit markedly different reactions when subjected to certain of the infectious diseases. This latter point bears directly on the problem, for inbreeding as a system produces pure or homozygous types. Hence the demonstration of such differences between inbred lines points conclusively to the fact that it is possible to concentrate factors for resistance or susceptibility to a given disease within certain strains.

From an evolutionary standpoint the latter fact has great theoretical interest. It is more pertinent in plants in some of which self-fertilization, the closest form of inbreeding, is the natural method of reproduction. It is within such highly inbred forms that naturally resistant lines of plants have been found to exist. During the evolutionary history of these plants it is probable that most of the diseases now common to them have been present for centuries. General outbreaks of these diseases have occurred from time to time and during such an outbreak only those plants possessing a natural resistance have survived. Such plants through self-fertilization have been from generation to generation the parent plants of the strains now existing. With inbreeding tending to produce homozygous types and with nature eliminating those types that were not pure or reasonably pure for resistance, the result has been the gradual evolution of races or strains pure for resistance to a given disease. In those instances in which resistance was dependent upon only a few factors such strains were undoubtedly produced in a few generations, whereas if resistance depended upon many factors the production of such strains was very likely a much longer process. The speed of production of resistant lines was also probably affected by the frequency and severity of the infections. For instance, if infection occurred every year in a severe form the production of such types would be relatively a quick process. If, however, as is more probably the case, severe outbreaks of the disease were rather infrequent due to lack of favorable environment, the production of resistant strains would be proportionally slower.

In the higher animals crossbreeding is the normal method of reproduction, and

such a method permits the impure or heterozygous types to remain about the same from generation to generation. As a result homozygous types have not been produced and accordingly this method of reproduction undoubtedly has accounted for the lack of disease-resistant types of animals. For centuries nature has been selecting each generation only those individuals equipped with the proper inheritance to withstand disease, but unfortunately such individuals have generally been impure or heterozygous for the resistant factors. Because outbreeding perpetuates these heterozygous types, resistant lines of animals have not been evolved, and the race has tended to revert to a generally heterozygous condition. Conceivably, if the disease had occurred every year in very severe form entirely resistant races might have been produced, but such was not likely the case. That such a tendency has been apparent, however, is shown by the aforementioned fact that uncivilized or isolated races are much more susceptible to diseases of the civilized races than are the people of a region in which those diseases have been prevalent for centuries.

If nature has been able to evolve completely resistant lines in naturally inbred species, and has shown a tendency toward producing partially resistant lines in outbred species, it is reasonable to believe that by rigid selection based upon an animal's ability to produce resistant offspring, the use of a moderate amount of inbreeding and with constant exposure to a virulent type of the disease, naturally resistant strains of animals may be produced. With these reasons in mind the problem of producing a strain of chickens having a sufficiently high natural resistance to withstand general epidemics of fowl typhoid was undertaken in the writer's laboratory. While the ultimate goal is far from achievement, some facts of general interest have accumulated.

As foundation material healthy mature chickens were selected and each bird was fed the same quantity of a virulent culture of fowl-typhoid bacteria. From the survivors of this group those birds that had shown the least reaction to the disease were selected and used as breeding stock. The next year the chicks from these birds were infected with a standard dose of the fowl-typhoid bacteria, a dose that in preliminary tests had been found to be lethal for approximately 90 per cent. of all chicks secured from ordinary outside sources. Concurrently with the infection of the chicks from the surviving parents an approximately equal number of chicks with similar breeding but from an outside source were also infected. The chicks from the surviving parents showed a total mortality of 41 per cent., whereas those chicks that came from non-surviving parents gave a total mortality of nearly 90 per cent. This is a difference in mortality between the two groups of nearly 50 per cent., a difference that certainly can not have been due to chance alone, since over eight hundred chicks were used.

Thinking, perhaps, that a large part of this difference in resistance between the above groups of chicks might be transmitted in some manner through the yolk of the eggs of the surviving mothers, typhoid-surviving males were mated to hens of similar breeding that had not been exposed to fowl typhoid. The total mortality observed in the chicks of these matings was approximately 60 per cent., a figure intermediate between that of the first two groups. In this case the increased resistance of the chicks came from the sires alone, and since numerous experiments have indicated that passive immunity cannot be transferred from the male to his offspring, the resistance must have been due to factors for resistance resident in the germ cells of the sire. The reciprocal cross, namely typhoid-surviving

females × non-tested males, gave approximately the same results.

Not only in total mortality, however, was there a difference in the three groups of chicks. The rate or speed of mortality exhibited the same general relationship. The chicks with double typhoid-surviving ancestry showed a slow rate of mortality; those with single typhoid-surviving ancestry, an intermediate rate; and the group with non-typhoid ancestry, a very rapid rate. This indicates a higher potential of resistance in those chicks whose parents had both withstood an attack of the disease, although, as indicated by total mortality, this potential was not high enough to protect all chicks against death from the infection.

It has been found, also, that sires differ markedly in their ability to transmit resistance to their progeny, a situation that would be expected if resistance to this disease were an inherited character depending upon a number of factors for its expression. These differences were so marked in some cases that there can be no question of their significance.

The findings reported herein have been accumulated over a period of three years and the relationships from year to year have been very consistent. This consistency indicates clearly that the hereditary basis for resistance is reasonably constant in any given strain of chickens. It has also shown that the experimental technique is sufficiently accurate to enable us to predict within fairly close limits what may be expected in any given trial.

Another experiment dealing with the same general problem has been carried on in this laboratory, using the rat as the experimental animal. It has been proven beyond question that selection is effective in producing inbred lines of rats having a much greater resistance to the Danysz bacillus than that existing in an unselected population. Furthermore it has been shown that the second selected generation has a much higher degree of resistance than the first selected generation. Crosses between susceptible and resistant strains have also demonstrated that there is a genetic basis for resistance to disease that is transmitted through both the female and male rat. However, the immediate problem now is to develop by selection a strain of rats more highly resistant than any at present existent.

This demonstration of the possibility of selection is the main contribution of these experiments to date. Whether selection based upon the above basis will result in the eventual development of naturally disease-resistant animals remains to be seen. The possibility has been clearly indicated but many unforeseen difficulties may be ahead of its ultimate accomplishment. If accomplished, the value of such experiments will be untold. Chiefly, perhaps, from the practical standpoint, but not alone, for many problems in immunology and bacteriology may be solved only when hosts that can be depended upon to react in a constant and definite manner toward certain microorganisms become available. And lastly if they should help in an eventual revival of the idea of constitutional fitness as one of the sound policies of eugenics they may result in vast benefits for mankind in ages to come.

CHILDREN OF THE SUN

By Professor JOHN HODGDON BRADLEY, Jr.
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A SEA whose shores no eyes have ever seen, whose depth no instrument can fathom, whose waters no scientist can analyze—such is the sea of space. Nothing can be as empty and cold as the gulf wherein our destinies are immersed. Star worlds, like fish in schools, drift through the void, star worlds as large as our sun and many times larger, in schools of hundreds of millions. Unlike a school of fish, whose direction may be changed by a whim of the leader, whose organization may be destroyed by the rush of an enemy, whose fate is in the hands of a shifty environment, the stars in their galaxy move with the majesty of perfect orderliness. From the smallest satellite slave of the smallest star to the largest super-galaxy of worlds in space, everything bows to the first law of nature. Chaos and caprice do not exist.

Hundreds of millions of stars are visible to the powerful eyes of astronomy. They are grouped in the shape of a thin watch whose greatest diameter is ten to fifteen times the thickness. Light consumes perhaps as much as one hundred thousand years in traveling along the equator of the disk, light which moves at the speed of more than 186,200 miles in a second and can circle the earth seven times during one beat of the human pulse. The Milky Way, where the stars seem more thickly grouped, reveals our position in the galaxy. We are near the outer edge, and when we see the clotted light of the Milky Way, we are looking through the long diameter of our universe. Many kinds of stars are brothers of our sun, stars of incandescent gas, dark dead stars burned to cinders, single and multiple stars in open and closed clusters, stars in vast irregular clouds, as well as much nebulous fire-mist of uncertain character. Everything is in motion, not only the galaxy as a whole, but all the minor states in the republic of suns.

Our own sun, with its coterie of devoted attendants, wends its way through the swarm, held by the mysterious power that keeps the worlds in our universe together and pulls them ever into more intimate association. Copernicus violated the vanity of men when he proved the earth a mere satellite of the sun. Modern astronomy goes further and paralyzes the imagination. Our sun is but one among hundreds of millions. And the hordes of visibly blazing suns are probably not all. Dead stars, like dead men, may be more numerous than live ones. Outside our galaxy are other universes, similar to our own in shape and size, so distant that their light reaches us only after a million years.

Like jetsam in an ocean current, the sun and her small family voyage through space and time, with man a microbe on a drifting fragment, a molecule in an infinity, a moment in an endless day, lost in the cosmos, his purpose as obscure as his destination. Fortunately for his peace of mind, man's philosophy does not often rise to astronomical heights. The largest star in the firmament might disappear for all he cares. His concerns are down on earth with his problems. Yet he may well take some interest in the universe without. From a catastrophe in this universe his life began, and from a similar catastrophe it may some day end.

No modern scientist doubts that all the planets, moons, asteroids, meteors and comets in our solar system were born of the sun. The blood relationship of earth and sun has been proved by the spectroscope. This instrument breaks up the white light of the sun into a series of colors. Each color denotes the presence of a definite chemical element. The composition of the sun is thus known to be very similar to that of the earth. More than forty elements known upon earth are present in the sun. The other planets and their moons, the meteorites and the comets show no elements foreign to earth. The kinship of all members of the solar system is a clear fact.

The birth of the earth and her sister planets has inspired several guesses. For many years the views of the French astronomer, Laplace, were accepted. He thought the parent sun a nebula of hot gas with a diameter of more than five billion miles, sufficient to include the orbit of the outermost planet, Neptune. This mother nebula rotated slowly, shrinking and gaining speed as it cooled. A ring of gas was eventually detached, which condensed into a gaseous spheroid, rotating about the sun. Thus was the first child, the planet, Neptune, born. Again and again rings were thrown off the contracting sun, and Uranus, Saturn, Jupiter, Mars, Earth, Venus and Mercury in turn took up a separate existence. In similar fashion the planets gave off rings that collapsed into moons, rotating about the planets as the planets rotate about the sun.

But alas for theories that germinate in the minds of men! They wilt in the bright light of advancing knowledge. To-day any college freshman can know what Laplace could not have known, that in the evolution of a gaseous nebula, the high activity of the molecules would have scattered the materials of the rings in space before the rings could form; that even if the rings had formed, they could not have condensed into a spheroid. The lighter gases of the earth's atmosphere would have rushed into space, overcoming gravity with the indomitable energy of their molecules. Furthermore, the gas in the earth ring would doubtless have cooled to a solid long before the time when the gaseous moon ring was thought to have formed.

The nebular hypothesis has other failings. It is too simple to explain the complexities of movement in the solar system. There is much doubt that the mother nebula could have detached a ring before it had shrunk well within the orbit of Mercury, the innermost planet. If the views of Laplace were true, the satellites should revolve in the direction of the rotation of their planets. But one moon of Saturn and two moons of Jupiter revolve in the opposite direction. The planets should be rotating faster than their moons, and the sun fastest of all, because with cooling and contraction the speed of rotation should have increased. Yet Phobos, the inner satellite of Mars, circles its planet three times while the planet turns on its axis but once. Jupiter, with less than one thousandth of the mass of the solar system, has most of the movement, movement which according to the theory should be invested in the sun.

Thus it is that the nebular hypothesis must blush before the facts of modern physics and astronomy. But youthful sciences grow vigorously and old tissues of theory are replaced by new. The nebular hypothesis will take its place in the history of sciences as a boon to progress through its very errors. For men must have a cosmogony, and false cosmogonies, like false gods, drive the thoughtful to search for the ultimate truth.

Perhaps the greatest contribution to theoretical science since the Darwinian renaissance in biology was the planetesimal hypothesis of Professors Chamberlin and Moulton, of the University of

Chicago. Like the savants before them, they believe the earth an offspring of the sun, but unlike Laplace, they allow her not only a mother but also a father. A star is thought to have passed near enough the ancestral sun to exert a gravitative pull. Even now the sun is belching incandescent materials from its surface almost three hundred thousand miles into space and at the rate of more than three hundred miles a second. Normally these materials fall back into the sun. But at the time when the solar system was destined to come into being, great arms of this eruptive stuff are thought to have been forced from either side of the sun and bent into spirals by the attracting force of the visiting star as it passed by. The sun was not strong enough to pull back its substance after the star had moved on, so that the ejected matter in the spiral arms remained detached. In the cold of space this gaseous material quickly froze to solid bodies that took the form of knots, some large and some small, with many finer particles between. All bodies thus formed revolved in elliptical orbits about the sun.

In time the large knots in the spiral arms collided with the smaller particles because of the eccentricities of the elliptical orbits. Slowly the large knots grew larger, absorbing by means of their superior gravity the lesser material in their paths. Each knot was the forerunner of a planet, and grew by sweeping up the smaller planetesimals. The satellites, growing in the same way, never became as large as the planets because they were smaller at the start. With every collision the planetary orbits were modified from the elliptical toward the circular. It is a striking fact that the largest planets, Jupiter, Saturn, Uranus and Neptune, which are supposed to have absorbed the greatest amounts of planetesimal material, have nearly circular orbits, whereas the insignificant planetoids, by-products of the solar system, move about the sun in highly eccentric pathways. Variation in the manner and rate of infall of the planetesimals accounts for the fact that some planets spin slowly and others rapidly, and that three satellites move in a retrograde direction.

The planetesimal hypothesis is the best cosmogony modern science can offer because it best explains the known facts of the solar system. But modifications of certain details have been argued. Barrell maintained that planetesimals of considerable size must have fallen upon the solid earth nucleus with force and rapidity enough to melt the growing planet. Jeans and Jeffries believe that the planets and their satellites were gaseous and liquid from the beginning. The advocates of the planetesimal hypothesis insist that the earth grew slowly, predominantly cold and solid throughout its history.

Unfortunately, vital facts necessary to prove any of these assumptions are buried beneath the accumulated rock debris of later eras. If the earth had condensed from a liquid, we might expect to find remnants of the original crust that formed over the cooling globe, like slag in a blast furnace. Nowhere has the prying eye of science made such a discovery. If the earth had been built slowly from cold planetesimals, we might expect to find traces of such material. But nature yields no easy victories; change has obscured or destroyed the record. With our present knowledge we can know but one thing with certainty, that the earth could not have been both liquid and solid at the same time. In a wilderness of speculation the path to truth is hard to find. Yet time and its revelations may some day point the way.

For the present we must be content with two stories about the early history of our planet. One or the other may eventually be proved true, but it is not

impossible that both are false. Those who believe the earth solid from birth see it first as a knot of solid material about one tenth the present size. Slowly this nucleus gathered to itself the star-dust in its path. The infalling planetesimals were not large enough to liquify the earth, but the heat of their impact liberated some gas. As the globe grew larger its gravity was able to prevent the escape of part of this gas. The blanket of the atmosphere began to form. At the same time, decay of radioactive minerals generated heat, internal pressure in the growing earth increased and developed more heat, easily fusible rocks were changed to liquid in pockets, volcanoes were born, more gas was given to the atmosphere. The water vapor in the young air was multiplied until some of it condensed as rain. Pools of water stood on the earth's rocky surface. Low areas were eventually filled with water and the oceans began their long careers.

Life came as a natural result of favorable conditions. Its past has been a long struggle toward perfection. Its future may be glorious beyond even the dreams of the past. For life will go struggling on as long as it is allowed to exist, and the end of present conditions is lost in the future.

Those who believe in a formerly liquid earth tell a sadder tale, of an earth that yesterday was steaming under the white heat of Hades, and to-morrow will be as cold and dead as the moon. The whole solar system is running down. Life is but lightning flashing in a troubled night, destined to vanish with the day. We now enjoy the special conditions necessary to our existence, enough air and water, temperature of the correct range. But the earth is stiffening in death. It will freeze to the absolute zero of space. Man and all his lower relatives will breathe no more. The sun and her children will continue to swing through space and time, the past but a memory of glory lost, the future devoid of hope.

At present we can not know, but time may yield the truth. Meanwhile lovers will go on with their love, politicians with their wars, and scientists with their theories.

THE AUTOCHTHONAL TALE OF JACK THE GIANT KILLER

By HARRY B. WEISS

NEW BRUNSWICK, N. J.

In spite of Cotton Mather's exemplary "Elizabeth Butcher" who, when she was two and a half years old, asked herself, "What is my corrupt Nature?" and answered herself, "It is empty of Grace, bent unto Sin, and that continually," and in spite of her practice, when she was six years old, of carrying "her Catechism or some other good Book to Bed with her," and getting up early the next morning to read it—in spite of the example set by this pious little lady of Boston, New England must have harbored a number of depraved little wretches who gave no heed to their corrupt natures and who took to bed with them, not catechisms, but copies of "The Pleasant and Delightful History of Jack and the Giants." And who could blame them when the title page promised "A full Account of his Victorious Conquests over the North Country Giants; destroying the inchanted Castle kept by Galligantus; dispers'd the fiery Griffins; put the Conjuror to Flight; and released not only many Knights and Ladies, but likewise a Duke's Daughter, to whom he was honourably married." Giants, fiery griffins, conjurors, castles, knights and ladies—direct from Nottingham, Newcastle, Banbury and London—with pictures of Jack strangling the giants, playing tricks and otherwise performing strictly as advertised on the title page—all for one penny.

Although it may seem incredible, there are actually some people so old that they either have forgotten the adventures of Jack the Giant Killer, or have him hopelessly confused with Jack and the Bean Stalk, and so for the purpose of setting these unfortunates straight, it may be well to review, briefly, the "pleasant and delightful history of Jack and the giants."

Jack, the son of a wealthy farmer, flourished during King Arthur's time, in England, which country suffered from the thieving propensities of a race of dumb but troublesome giants. His first adventure consisted in outwitting the giant Cormoran, of Mount Cornwall, by digging a pit, into which Cormoran fell, and then neatly dispatching him by a blow on the head from a pick-axe. The news of this outrage reached the giant Blunderboar, who lived in an enchanted castle in Wales, and Jack was unfortunate enough to fall into Blunderboar's hands. He was locked in a room of the castle while Blunderboar hunted up his brother so that both could enjoy the killing. However, Jack found two strong cords in his room, and while the giants were unlocking the gate, he managed to get running nooses over their heads and of course they died of strangulation. Next, a Welsh giant, with two heads, who appeared friendly, invited Jack to a room in his house, and Jack would surely have lost his life in the night had he not substituted a billet of wood for himself, in bed, which billet the giant struck with a great knotty club. The next morning at breakfast, Jack, instead of eating four gallons of hasty pudding, managed to slip it into a leather bag under his coat, then telling the giant he would show him a trick,

he ripped the bag open and the pudding plopped out. The giant, wishing to imitate such a delightful trick, ripped open his own *scrobiculus cordis*, his "tripes and trullibubs" fell out and that was the end of him.

Jack then met King Arthur's son and both of them visited a three-headed giant who had a tremendous reputation as a fighter. Jack, however, so scared this giant by telling him that the King's son with a thousand men was on his way to kill him, that the giant begged Jack to lock him up in a vault until the prince had departed. This Jack did and the grateful giant presented him with a coat which would make the wearer invisible, a pair of shoes of incredible swiftness, a cap of knowledge and a sword which cut asunder whatever it struck. With this magic equipment, Jack outwits the evil spirits who had enchanted a beautiful lady, thereby making it possible for the prince to wed her. All then return to the court of King Arthur, where Jack is received with acclaim and made one of the Knights of the Round Table.

Jack then adopted giant-killing as a vocation, and after being supplied with money and a horse, he started out to rid the realm of "cruel and devouring monsters." Against his magic trappings the giants did not have the ghost of a chance. He cut off giants' legs, noses and heads, rescued worthy knights and fair ladies, distributed treasures, outwitted the two-headed Thunderful, author of "Fe, Fi, Fo, Fum," etc., and sent his heads to King Arthur. But his crowning achievement was the slaughter of Galligantus, who collaborated with a conjurer in transforming knights and ladies, including a duke's daughter, into "sundry shapes." Jack passed the fiery griffins, wearing his invisible coat, and having reached the gate of the castle he blew a golden trumpet which hung there. This caused the castle to tremble, and just as Galligantus stooped to pick up his club, Jack decapitated him with his sword of sharpness. The conjurer was carried off by a whirlwind, the castle vanished and the knights and ladies assumed their proper forms. Upon their return to the Court of King Arthur, Jack married the duke's daughter and lived happily ever after in "a noble house, with a large estate."

This brief and inadequate summary does not, of course, give one any idea of Jack's cunning over the stupid giants, of his ready wit, of his entertaining conversations with the giants, of how he liberated fair ladies, of how the giants ate men's hearts and livers with pepper and vinegar, of the dreadful shrieks which emanated from knights and ladies being held by the hair of their heads, of the terrible appearance of some of the giants, with eyes of fire and cheeks like sides of bacon; for these, one must consult a version which has not been softened by the Society for the Supervision of Children's Reading, or whoever it is that does such things.

The oldest edition of this nursery tale appears to be one dated 1711, supposedly in the British Museum, entitled "The History of Jack and the Giants" (12mo. n.d.). "The Second Part of Jack and the Giants, giving a full account of his victorious Conquests over the North Country Giants, destroying the Enchanted Castle kept by Galligantus, dispers'd the Fiery Griffins, put the Conjuror to flight, and released not only many Knights and Ladies, but likewise a Duke's Daughter, to whom he was honourably married." (12mo. Newcastle, 1711.) This edition is illustrated by rude woodcuts, representing the important events of the history. The tale was current, however, long before 1711. In "King Lear" (c. 1605) Edgar as Mad Tom says:

> Child Rowland to the dark tower came;
> His words were still "Fee, fow and fum!
> I smell the blood of a British man."

And in "Have with you to Saffron Walden," 1596, by Nash, there is mentioned "a precious apothegmaticall pedant who will finde matter inough to dilate a whole daye of the first invention of

Fy, fa, fum,
I smell the bloud of an Englishman!"

Sir Francis Palgrave believed that Jack the Giant Killer was one of the popular stories founded upon King Arthur and his adventures, although certain features of the latter are to be found in popular Asiatic tales. In Malory's "Morte d'Arthur" (1485), Arthur's fight with the giant of St. Michael's Mount is told in frightful detail.

Thenne the gloton anone starte vp and tooke a grete clubbe in his hand / and smote at the kynge that his coronal fylle to the erthe / and the kynge hytte hym ageyn that he carf his bely and cutte of his genytours / that his guttes and his entraylles fylle doune to the ground / thenne the gyaunt threwe awey his clubbe / and caught the kynge in his armes that he crusshyd his rybbes / Thenne the thre maydens knelyd doune and callyd to Cryst for helpe and comforte of Arthur / And thenne Arthur weltred and wrong / that he was other whyle vnder and another tyme above / And so weltryng and walowynge they rolled doune the hylle / tyl they came to the see mark / and ever as they soo weltred / Arthur smote hym with his daggar / and it fortuned they came to the place / where as the two knyghtes were and kepte Arthur hors / thenne when they sawe the kynge fast in the gyaunts armes / they came and losed hym / And thenne the kynge commaunded syr kaye to symte of the gyaunts hede / and to sette it vpon a truncheon of a spere / and bere it to syr howel / and telle hym that his enemy was slayne. (Book V, chap. v.)

Malory's sources were French and English, and to them he added detail and his own interpretation.

Although Arthur figures as a successful general in the "Historia Britonum" (c. 810) by Nennius, who expanded and redacted preexisting compilations, Geoffrey of Monmouth is usually called the father of Arthurian romance. Geoffrey, for his "Historia Regum Britanniae," published about 1136, gathered his material, according to L. C. Paton, from "episodes in the chronicles of his contemporaries, William of Malmesbury, and Henry of Huntingdon, from ancient Celtic records, the legends of Celtic saints, Celtic myth, Biblical history, classical and Scandinavian stories, the universal stock of folk-tales, local British tradition, the Carolingian cycle, familiar facts of general history, and from events in the life about him."

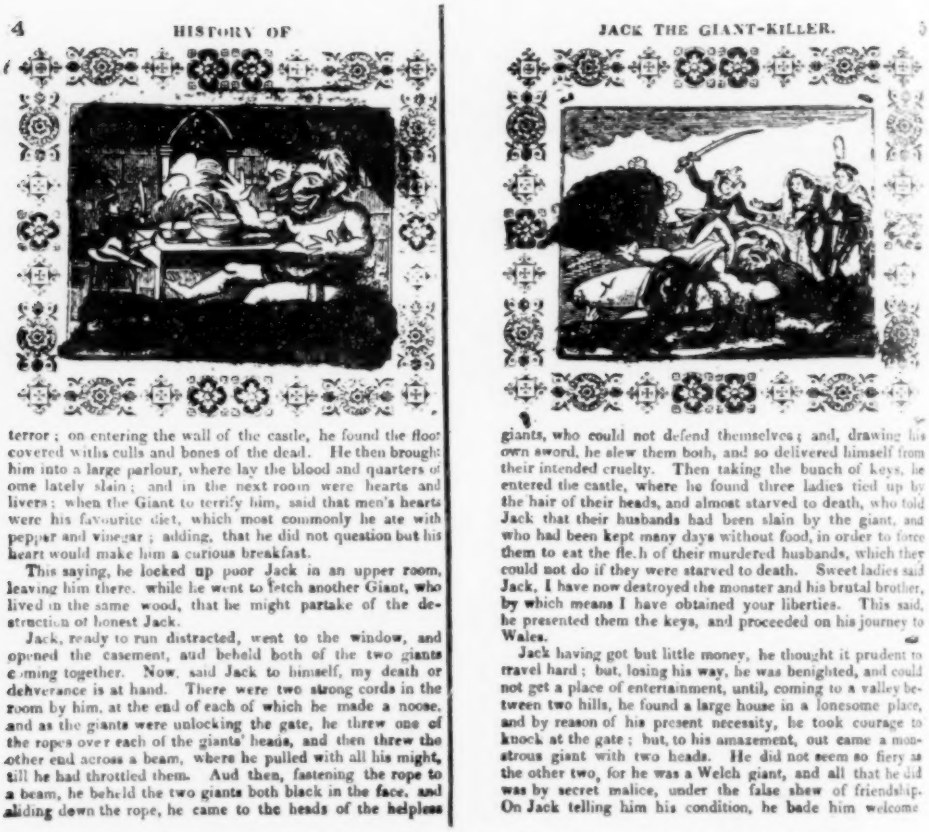
In chapter III, Book X, of the "Historia," King Arthur meets on Mount Michael the giant who had captured Helena, niece of Duke Hoel.

The King forthwith unsheathed his sword, and covering him with his shield, hurried as swiftly as hurry he might to be beforehand with him, and prevent his getting hold of the club. But the giant, not unaware of his intentions, had already clutched it and smote the King upon the cover of his shield with such a buffet as that the sound of the stroke filled the whole shore, and did utterly deafen his ears. But Arthur, thereupon blazing out into bitter wrath, lifted his sword and dealt him a wound upon his forehead, from whence the blood gushed forth over his face and eyes in such sort as well-nigh blinded his sight. Howbeit, the blow was not deadly, for he had warded his forehead with his club in such wise as to scape being killed outright. Natheless blinded as he was with the blood welling forth, again he cometh on more fiercely than ever, and as a wild boar rusheth from his lay upon a huntsman, so thrust he in within the sweep of Arthur's sword, gripped him by the loins, and forced him to his knees upon the ground. Howbeit, Arthur, nothing daunted, soon slipped from out his clutches, and swiftly bestirring him with his sword, hacked the accursed monster, first in one place and then in another, and gave him no respite until at last he smote him a deadly buffet on the head, and buried the whole breadth of his sword in his brain-pan. The abhorred beast roared aloud and dropped with a mighty crash like an oak torn up by the roots in the fury of the winds. Thereupon the King brake out on laughing, bidding Bedevere strike off his head and give it to one of the squires to carry to the camp as a rare show for sightseers.

TITLE PAGE OF FORTEY'S "HISTORY OF JACK THE GIANT KILLER," PUBLISHED ABOUT 1840.

The English version of Jack the Giant Killer is also said to have been adapted from the story of Corineus the Trojan, found in Geoffrey's "History of the Kings of Britain."

It has been stated that the earliest form of Jack the Giant Killer in western lore is probably the account of Thor and the giant Skrymir, found in the collection of the celebrated Icelandic historian, Snorri Sturluson, known as "Edda Snorra" (between 1140 and 1160). In this old Scandinavian folk-tale entitled "Thor's Journey to the Land of Giants," Thor becomes enraged because he can not open the giant's bag, which contains their provisions, and hurls his hammer at the head of the sleeping giant. This awakens Skrymir, who asks if a leaf has not fallen upon him. A second time Thor uses his hammer, driving it into the giant's brain, upon which the giant



4 HISTORY OF

terror; on entering the wall of the castle, he found the floor covered with skulls and bones of the dead. He then brought him into a large parlour, where lay the blood and quarters of some lately slain; and in the next room were hearts and livers; when the Giant to terrify him, said that men's hearts were his favourite diet, which most commonly he ate with pepper and vinegar; adding, that he did not question but his heart would make him a curious breakfast.

This saying, he locked up poor Jack in an upper room, leaving him there, while he went to fetch another Giant, who lived in the same wood, that he might partake of the destruction of honest Jack.

Jack, ready to run distracted, went to the window, and opened the casement, and beheld both of the two giants coming together. Now, said Jack to himself, my death or deliverance is at hand. There were two strong cords in the room by him, at the end of each of which he made a noose, and as the giants were unlocking the gate, he threw one of the ropes over each of the giants' heads, and then threw the other end across a beam, where he pulled with all his might, till he had throttled them. And then, fastening the rope to a beam, he beheld the two giants both black in the face, and sliding down the rope, he came to the heads of the helpless

JACK THE GIANT-KILLER. 5

giants, who could not defend themselves; and, drawing his own sword, he slew them both, and so delivered himself from their intended cruelty. Then taking the bunch of keys, he entered the castle, where he found three ladies tied up by the hair of their heads, and almost starved to death, who told Jack that their husbands had been slain by the giant, and who had been kept many days without food, in order to force them to eat the flesh of their murdered husbands, which they could not do if they were starved to death. Sweet ladies said Jack, I have now destroyed the monster and his brutal brother, by which means I have obtained your liberties. This said, he presented them the keys, and proceeded on his journey to Wales.

Jack having got but little money, he thought it prudent to travel hard; but, losing his way, he was benighted, and could not get a place of entertainment, until, coming to a valley between two hills, he found a large house in a lonesome place, and by reason of his present necessity, he took courage to knock at the gate; but, to his amazement, out came a monstrous giant with two heads. He did not seem so fiery as the other two, for he was a Welch giant, and all that he did was by secret malice, under the false shew of friendship. On Jack telling him his condition, he bade him welcome

PAGES 4 AND 5 OF FORTEY'S "HISTORY OF JACK THE GIANT KILLER."

again awakens and asks if an acorn has not fallen on his head. A third time, Thor buries his hammer in the giant's cheek, with the result that Skrymir again is aroused from his sleep and asks if some moss has not fallen on him. Later in the tale it appears that in every case the sly Skrymir had substituted a rock for his person and so escaped the blows from Thor's hammer. This story is similar to that of Jack's adventure with the Welsh giant, and Ashton cites this similarity as part of the proof of the northern origin of Jack the Giant Killer. As for Jack's coat which rendered him invisible, his cap of knowledge, his shoes of swiftness and his miraculously sharp sword, Ashton states:

To show the northern origin of this tale, it is only necessary to point out that the coat is identical with the magic garment known in ancient German as the "Nebel Kappe," or cloud cloak, fabled to belong to King Alberich and the other dwarfs of the Teutonic Cycle of Romance, who, clad therein, could walk invisible. To them also belongs the "Tarn Hut," or Hat of Darkness. Velent, the smith of the Edda of Sæmund, forged a "Sword of Sharpness," which in the Wilkina Saga is called Balmung. It was so sharp that when Velent cleft his rival, Æmilius, it merely seemed to the latter like cold water running down him. "Shake thyself," said Velent. He did so, and fell in two halves, one on each side of the chair. The Shoes of Swiftness were worn by Loke when he escaped from Valhalla.

Thomas Keightley, who wrote long before Ashton, called attention to the fact that Jack's strategy, in substituting a stick of wood for himself during his adventure with the Welsh giant, was not

JACK KILLS BLUNDERBORE.

JACK STRANGLES THE GIANTS.

JACK'S ARTFULNESS.

JACK SHOWS THE GIANT A TRICK.

THE GIANT AND HIS PRISONERS.

JACK SLICES OFF THE GIANT'S NOSE.

ILLUSTRATIONS FROM BYGONE EDITIONS OF JACK THE GIANT KILLER.

peculiar to English giant-killers, but was found also in the folk-tales of other countries. In addition to the tactics of Skrymir, Keightley mentions the German "Brave Tailorling" ("Das tapfere Schneiderlein") which deals with the adventures of a little tailor who had killed seven flies on his bread, all at one blow, and who was so proud of this that he wanted the whole world to know about it, although he was careful to state only that he had killed seven, not specifying what the seven had been. At the beginning of his travels he met a giant sitting on the top of a mountain, and after a comparison of feats in which both giant and tailor performed and in which the tailor came off best, by reason of his tricks, the giant invited him to spend the night in his cave. The tailor was smart enough not to lie in the bed but to hide in a corner instead, and it was well that he did so, for the giant came in during the night and with an iron club struck the bed a blow that sent the club through it. Keightley, after calling attention to the similar strategy of the giant Skrymir and the little tailor, suggests the possibility of Jack the Giant Killer having been brought into England by Anglo-Saxon or Danish ancestors by way of "Thor's Journey to the Land of Giants," and Sir Walter Scott believed that "Jack" landed in England "from

the very same keels and warships which conveyed Hengist and Horsa, and Ebba the Saxon,"[1] supposedly about 450–455. However, the device of "substitution" is found in the folk-tales of more distant countries, and this is noted by Keightley.

In the Persian story, "Ameen of Isfahân and the Ghool," supposedly from India, Ameen saves his life by the substitution of a pillow for himself, in bed, escaping a terrible blow from the Ghool's walking-stick which was as big as the trunk of a tree.

In Perrault's tale of "L'Adroite Princesse," Finetta manufactures a straw figure into which she puts a bladder of blood. Substituting this figure for herself, in bed, she escapes the sword of the prince. And in Giambattista Basile's "Il Pentamerone" (c. 1637, Naples), "Sapia the Glutton," heroine of the tale so called, makes a figure of pastry and sugar scented with musk. This she places between the bed sheets and then hides herself behind a screen. The prince Torre, whom Sapia had given much cause for worry, enters with murder in his heart and plunges a dagger into the confection. So terrible was he, that, desiring even to drink her blood, he licks the dagger, but tasting its sweetness and the scent of musk, he is overcome for having killed so sweet a girl and would have taken his own life on the spot had not Sapia come forth to console him.

According to Keightley, most of the circumstances of "Ameen of Isfahân and the Ghool," of "The Brave Tailorling" and of "The Goat and the Lion," one of the stories in "The Panchatantra," which assumed shape in India and spread through Persia, Arabia, Syria and European countries and whose already old tales were supposedly composed about 200 B. C. in Kashmir, are found in "The Lion and the Ass," one of the tales in Straparola's "Pleasant Nights." From this one may assume that the fable of "The Lion and the Ass" originated in India.

In "Notes and Queries" (3rd Ser. IX, pp. 515–16, 1866), H. C. advanced the opinion that the earliest form of Jack the Giant Killer in Western folk-lore was probably the tale of Thor and the giant Skrymir, and stated that in the East every Hindu school-boy knew of Beeman, one of the fine Pandus, and his giant-killing adventures, the Pandus being first mentioned in the "Mahabharata," written at least 240 B. C. He also stated that the words, "Fe, fi, fo, fum, I smell the blood of a man," were paralleled in a couplet spoken by a giantess in a Mohammedan tale called "Sunebal [golden-haired] and the Ogress," which he heard related in India.

Although there is a stronger human element in Jack the Giant Killer than in the strictly eastern tales of fairies, genii, etc., giant legends are common in Asia and Europe. The cannibalistic skin-clothed, stupid giants, armed with clubs and stones, may have been the savage tribes transformed into giants in the folk-lore of those who conquered them.

From the summary herewith presented, one may make the somewhat indefinite statement that Jack the Giant Killer is apparently of Indo-European origin and was probably introduced into England during the Saxon invasion.

Folk-tale happenings are widely distributed. Carried from one tribe to another and from one country to another and from one continent to another, there is often in the tale little intraneous evidence to indicate the origin either of native or foreign parts. European folk-tales are said to be remarkably uniform in content, although differing in speech and local color. Boas states that the frameworks of myths and folk-tales are almost exclusively made up of events

[1] "The Child and His Book," by Mrs. E. M. Field (London, 1892).

that reflect the occurrences of human life, especially those that agitate the emotions. The extremely fanciful character of the tales may be ordinary wishes or amplifications of our experiences, such as the smallness of dwarfs, bigness of giants or manifestation of objects of fear. Boas calls attention to the limited power of imagination in man and the tendency to use the old stock of inventive occurrences rather than to think up new ones, and also to the fact that the highly embroidered, more complex and locally colored tales are the result of more thought and attention being given to them by priests, poets and deeply interested persons.

Numerous English editions of Jack the Giant Killer have appeared since the one referred to, in the beginning of this paper, as having been published at Newcastle in 1711. Many are illustrated with delightfully crude woodcuts, sometimes frightfully and carelessly colored in red, blue, green and yellow, such as the Fortey (1850?) and the Otley editions. Bound in colored paper covers with their pictures of giants in various poses and succumbing to Jack's ingenuity, they must have delighted their juvenile readers immensely. Although the various early editions differ from each other, sometimes in their wording, their omissions and their abridgments, the versions are, for the most part, the same, and the essentials of the tale are retained. In some of the early editions, especially those intended for small children, Jack's sprightly conversation and exchange of wit with a local clergyman, in the opening part of the tale, are omitted. Nowadays one may purchase beautifully printed, bound copies of Jack the Giant Killer, illustrated in colors by such artists as Margaret Campbell Hoopes, Hugh Thomson, H. M. Brock, Margaret W. Tarrant, Margaret Evans Price and others, and it is interesting to note the conceptions of the various illustrators over the two-hundred-year period. For the most part, the giants have maintained their brutish, unintelligent appearance, and Jack remains a dapper hero. These modern versions are essentially like the older ones. Here and there, expressions have been changed or omitted, and killings have been softened somewhat; sometimes the tales are abridged, and on the whole they are a little less concerned with all of the details found in the chapbook versions. During the passage of time the few coarse expressions of the early accounts have disappeared.

Although Jack the Giant Killer is still holding his own—and undoubtedly will continue to do so—at times one is fearful that he is being crowded out by the very large and varied amount of other types of children's reading matter that is so apparent in the bookstores of to-day.

THE STORY OF THE LIBRARY AT LOUVAIN

By Dr. FRANK PIERREPONT GRAVES

NEW YORK STATE COMMISSIONER OF EDUCATION AND CARNEGIE VISITING PROFESSOR OF INTERNATIONAL RELATIONS

To judge from the press, American interest in the new library at the University of Louvain has been centered in the dispute over a proposed inscription on the balustrade. This inscription read, *Furore teutonico diruta, dono americano restituta*, which was commonly translated, "Destroyed by German fury and restored by American generosity," and the controversy raised the old question of "to be or not to be." To the university authorities it seemed abhorrent to immortalize in stone the fact that the building had been "destroyed by German fury," and thus maintain forever the spirit of war. As a matter of fact, too, the university building that had actually been destroyed was in quite another part of the town and had already been marked with an inscription.

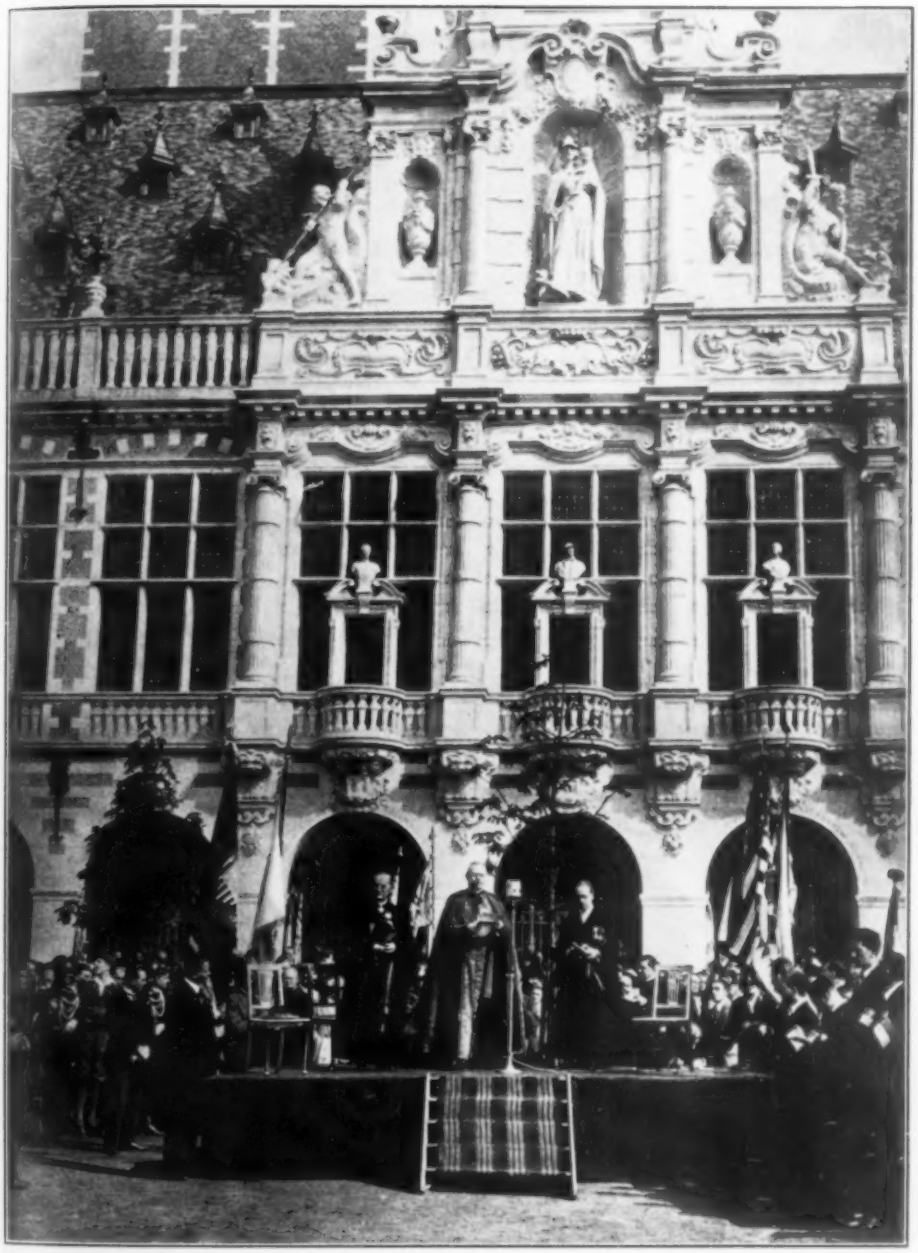
Representatives of the American donors were at one with the university in opposing such a perpetuation of hate. In addition, most of them found the second clause almost as distasteful as the first. Whatever other nations may think of us, Americans in general do not desire to blazon their good deeds from the housetops. The National Committee for the Restoration of Louvain, the Carnegie Endowment for International Peace and the Commission for Relief in Belgium, which had collectively made the building possible, all held that the decision as to what the character of the building should be rested entirely in the jurisdiction of the university authorities, and as far as American contributors were concerned, an inscription of the sort proposed could not possibly meet with approval.

But the talented architect of the library, Whitney Warren, could not see matters in this light. He held that the withdrawal or modification of the inscription would ruin his building and that as its artificer he had absolute right to determine every portion of its appearance. To justify the form of the inscription, he declared that it had been approved by Cardinal Mercier himself, who first inspired the restoration of the university library and whose name was a *shibboleth* to Americans and Belgians alike. The nationalists among the Belgians at once espoused the cause of the architect and violently attacked the rector of the university in public print.

The *impasse* that followed this serious difference of opinion has proven most spectacular and has attracted the attention of Americans everywhere. But the controversy over the inscription was in reality a small incident in a great international event. Of completely overshadowing importance were the sympathy and aid elicited for the stricken university not only from the United States but from the entire civilized world as well. The bitterness engendered, regrettable as it was, sinks into insignificance when compared with the dedication of such a magnificent building, testifying to our admiration for Louvain and enabling it to continue its work through the coming centuries. The story is worth narrating in all its picturesque setting.

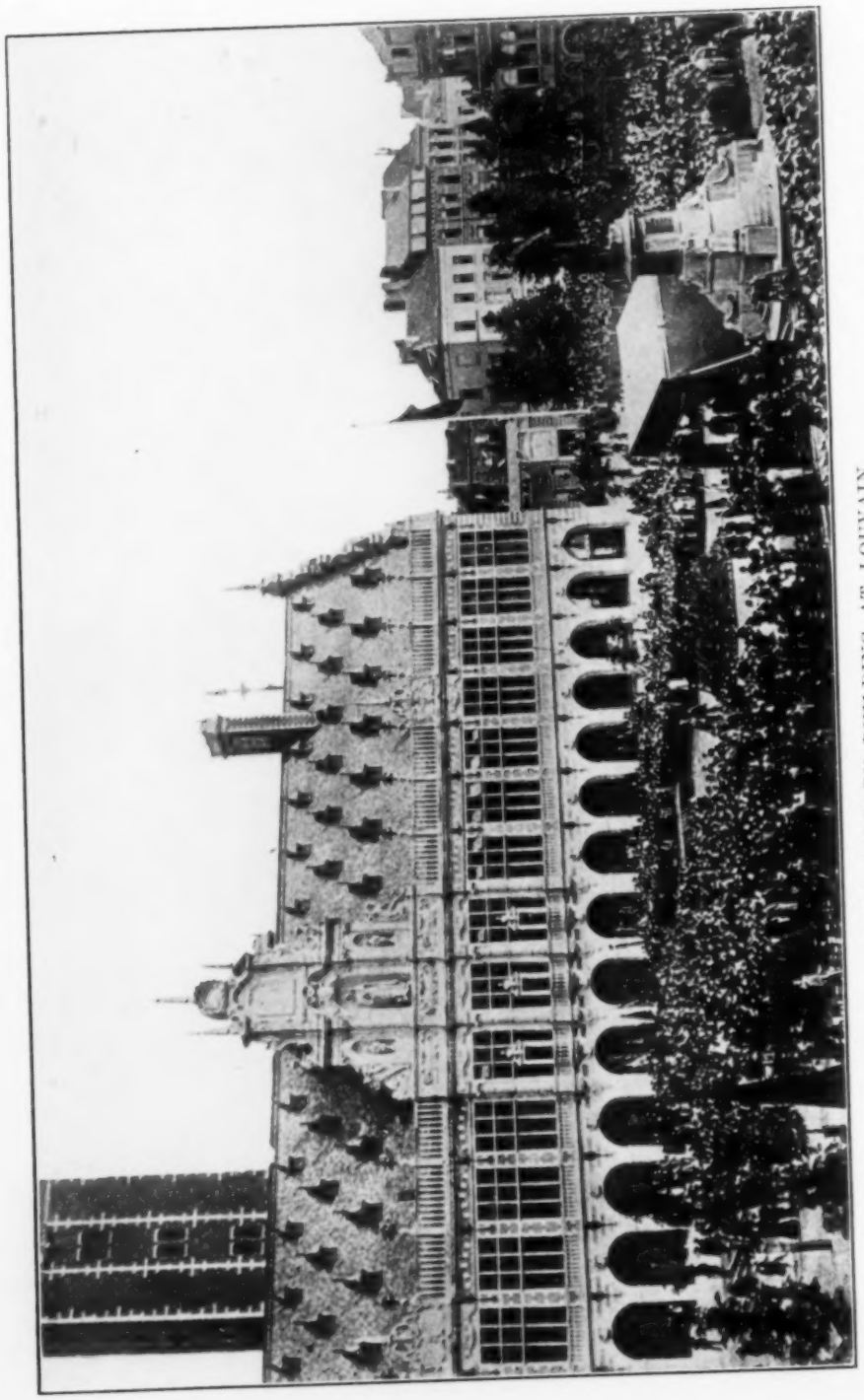
I

In the first place, no one would think of minimizing the outrage and loss to civilization connected with the destruction of Louvain and its famous uni-



THE PRESENTATION OF THE OFFICIAL ADDRESS OF THANKS

THE CARDINAL, PRESIDENT EX-OFFICIO OF THE UNIVERSITY BOARD OF TRUSTEES, IS SPEAKING IN FRONT OF THE BUILDING AND OPPOSITE THE TRIBUNE OF HONOR. THE PHOTOGRAPH ALSO AFFORDS A NEAR VIEW OF THE ORNAMENTATION OF THE FAÇADE.



THE LIBRARY BUILDING AT LOUVAIN

MADE POSSIBLE THROUGH AMERICAN CONTRIBUTIONS AND THE GENIUS OF WHITNEY WARREN. THIS PICTURE IS A WIDE WORLD PHOTO. THE OTHER ILLUSTRATIONS WERE ORIGINALLY PUBLISHED IN *Le Patriote Illustré* OF BRUSSELS.

versity. The magnitude of the calamity can scarcely be overestimated. For nearly five hundred years before the invasion of Belgium the University of Louvain had been a notable center in every advanced movement of education. It was, for example, among the earliest of the universities to have its medieval curriculum transformed by the spirit of humanism. For many years that wandering scholar of the Low Countries, the great Desiderius Erasmus, here found sympathetic friends, and by his teaching raised Louvain to a position of supremacy second only to Paris. Other distinguished humanists, like Vives, Rescius and Clenard, were attracted by the reputation he gave the institution, and toward the close of the sixteenth century, largely through the lectures of the famous professor, Justus Lipsius, Louvain came to have fifty-two colleges and some six thousand students.

Similarly, during every succeeding epoch in educational progress, this institution became the home of some of the more reputed scholars of the time. Here, when science began to awaken, taught Vesalius, the founder of modern anatomy, Dodoens, the botanist, and Mercator, who left a lasting impression upon geography. Over the destinies of Louvain in the seventeenth century presided Cornelius Jansen, who formulated one of the few unique systems of thought the world has known. While during the next century the university lost in numbers and reputation and was closed for a time during the disturbed period of the French Revolution, it was revived during the nineteenth century and largely recovered its high standing in science, literature and politics. Its scientific investigations have now a wide repute. While poorly endowed, it has for years maintained the largest institute of cancer research in the world, and ranks among the leading universities in the advancement of engineering and agriculture. It has become the nursery of modern Belgian literature, and during their student days nurtured such men as Verhaeren, Geroud, Waller and Van Arenburgh. And so thorough has been its training that its graduates have continually held many of the highest public offices in Belgium.

Through all this progress and intellectual leadership of the university its library has necessarily been a workshop and a great center of inspiration. At the time of its destruction it contained but a quarter of a million volumes, which would not in our country mark it as one of the largest libraries, but it must be remembered that these works had been accumulating for five centuries and in many instances were world famous. Among them were a thousand rare manuscripts of the early Middle Ages, hundreds of *incunabula*, the precious "books of hours," early publications of the first reformers, historic politico-religious pamphlets, polemic writings of the seventeenth century, successive editions of the Bible and many other rare works impossible to replace. Moreover, since Louvain was training about one half of the students of Belgium and hundreds from other countries, the injury wrought by the invasion could be paralleled only by the destruction of the libraries of a dozen or two of our greatest universities.

This destruction may be considered an act of "German fury" if you will, but it is only typical of the extremes to which the war madness will go. It is a demonstration rather of the utter futility of warfare and of the ruin that falls upon mankind when the primitive instincts and passions of our infra-human ancestry are once allowed to slip their leash. The destruction of the library at Louvain served absolutely no purpose, not even that of the exigencies of war or of robbery and pillage. It was the natural offspring of the war demon, and rendered the civilized world furious.

MADE POSSIBLE THROUGH AMERICAN CONTRIBUTIONS AND THE GENIUS OF WHITNEY WARREN. THIS PICTURE IS A WIDE WORLD PHOTO
OTHER ILLUSTRATIONS WERE ORIGINALLY PUBLISHED IN *Le Patriote Illustré* OF BRUSSELS.

II

Only a short time after the destruction, the sympathy and common humanity of the United States and other civilized nations began to manifest themselves. Efforts at reparation were started almost immediately. As an outcome the *Oeuvre International de Louvain* was formed, with national committees in each country, and by the time that the first wing of the new library was completed the books ready for its shelves had already run into hundreds of thousands. The honor of constructing a suitable new building was conceded to America. The first half million for this purpose was raised by our National Committee and the Carnegie Endowment, under the direction of Nicholas Murray Butler, mostly through small contributions, but gifts of considerable size had later to be raised to complete the necessary million and the hundred thousand additional needed for upkeep. Here the largest contribution was made by the Commission for Relief in Belgium, of which Herbert Hoover was the president.

A VIEW OF THE TOWER FROM THE SIDE

A VIEW OF THE TOWER FROM THE FRONT

The building resulting from these donations is a triumph in architecture. By a happy thought it has been designed in complete harmony with the fifteenth and sixteenth century aspect of the town, and while from its great architectural beauty and its imposing site on the *Place du Peuple* it dominates the surrounding country, it fits easily and naturally into the perspective. The architect has laid aside all American traditions and likewise avoided the temptation to indulge in columns and classic orders, and has created a building in the style of the Flemish Renaissance. Its characteristic feature is the wide vaulted *loggia*, or covered arcade, with seventeen arches, which underlies the principal façade.

The façade itself is adorned with sculptures, bas-reliefs, busts and statues, which are both memorial and symbolic. The central *motif* is the armed Virgin. Clad in a cuirass, she wears on her head the poilu's helmet, and her right hand rests upon the sword of the Crusaders, while her left supports the Holy Child. Our Lady of Victories is flanked by

figures of St. George and St. Michael crushing evil spirits. Above these decorations is a bas-relief representing the destruction of the former library building, while underneath, above doors leading to three outside pulpits, are busts of the war heroes—King Albert, Cardinal Mercier and Queen Elizabeth. The graceful tower, 275 feet in height, with the carillon given by the engineers, typifies the voice of the university—the voice of truth. Every hour the bells play a few bars from the Star-spangled Banner, the Brabançonne, the Marseillaise, or other national airs of the Allies.

III

The dedication of this most appropriate building was, out of compliment to the United States, set for the fourth of July. As the visitor entered Louvain on that gala day, it appeared ablaze with decoration. The emblems of the United States and France were everywhere intermingled with those of Belgium and the University of Louvain. Nearly every house in the medieval city bore at least two or three flags. The façade of the richly fretted Gothic town hall was a symphony of color. At the *Place du Peuple*, in front of the new library, where the ceremonies were to be held, workmen were until the last moment beautifying the grounds and preparing them for the celebration. Facing south toward the library there had been erected for the notables of the occasion a covered "tribune" of honor, fitted out with purple velvet and gold fringe. Opposite the tribune and much nearer the library a platform had been built for the speakers and equipped with a microphone that carried to all parts of the grounds. In the center of the enclosure, between the pavilion and the speakers' stand, a circular plot of palm trees had been tastefully arranged. On the right and left of the tribune and at right angles to it hundreds of chairs were reserved for the Belgian civil, ecclesiastical, military and academic authorities, and for the innumerable delegates and invited guests from other countries.

The colorful academic parade began at two o'clock. It was preceded by an escort of mounted police and companies of gendarmes and soldiery. This vanguard was followed, according to established custom, by a group of six heralds, all wearing steel helmets, blue tunics, coats of mail and leather leggings. Following them came the mace bearers, always so imposing a sight in the processions of old Continental universities. Then marched the delegates from various universities, Belgian and foreign, with the Americans in front. Last in the procession Monsignor Ladeuze appeared in full rectorial dress of black and red velvet, accompanied by Cardinal Van Roey, president *ex officio* of the University Board of Trustees and apostolic successor of the great Mercier.

The procession wound its way through the crooked narrow streets from Convocation Hall to the new building through a double line of honor composed of students of the university. When the library was reached, a tumultuous cheer burst from the throats of three thousand students, "*Vive le recteur!*" which was intended to voice their approval of his course with reference to the inscription and their adherence to constituted authority. On the front row of the tribune the rector took his place, and then in order came the American ambassador, the cardinal, the papal nuncio and the burgomaster of Louvain. Two chairs between the cardinal and the nuncio were left vacant for the royal personages, who were shortly to appear. The other chairs of the tribune were occupied by members of the Belgian cabinet, the French ambassador, the Belgian ambassador to Paris and the speakers of the day. Among the guests in the chairs near the tribune were the ambas-

THE GATHERING AT THE DEDICATION (LOOKING TOWARD THE TRIBUNE OF HONOR)

OCCUPANTS OF THE TRIBUNE OF HONOR

LEFT TO RIGHT. FIRST ROW: M. VAN DER VAEREN, BURGOMASTER OF LOUVAIN; MONSIGNOR MICARA, PAPAL NUNCIO; CROWN PRINCE LEOPOLD; CROWN PRINCESS ASTRID; HIS EMINENCE, CARDINAL VAN ROEY; HON. HUGH S. GIBSON, AMBASSADOR OF THE UNITED STATES; KING ALBERT; QUEEN ELISABETH; PRINCESS MARIE JOSÉ; PRINCE CHARLES; PRINCESS ANNE; PRINCE AUGUSTE, DUKE OF ARENBERG

sadors or ministers from a dozen other countries, the governors of the various Belgian provinces, the bishops of the archdiocese, the secretary of the Vatican library, generals in the Belgian army and the governor of the National Bank. After all these had been seated, the Theban trumpets sounded a fanfare and an automobile drove up with the crown prince and princess (the king and queen being absent in the Congo), who were then conducted to their places on the tribune amid the storms of applause from enthusiastic students and others.

IV

It was now two-thirty and the program began. First came the benediction upon the new building by the cardinal, assisted by the Belgian bishops. Invested with mitre and crosier the primate mounted the speakers' platform, faced the library and intoned the liturgical prayers. The responses were given by students in the Seminary of Malines, and the chants were magnified and diffused by a loud speaker fixed in the tower of the library. He then made a tour of both the exterior and the inside of the building, sprinkling the walls and purifying them with incense. As a final step the youngest of the bishops performed the rather perilous duty of ascending the spiral staircase of the tower and blessing the bells. At the conclusion of this ceremony the carillon pealed forth a chant of glory and resurrection and a select choir from the public schools raised sweet young voices in a *Cantate* of Peter Benoit's.

Then came the addresses by representatives of the American donors. Ambassador Hugh S. Gibson, representing the larger givers, spoke first. After his address he delivered to the rector the golden key to the new library. This was the signal for immense applause and from all sides came vigorous cries of "*Vive l'Amerique!*" From the summit of the tower the Theban trumpets blared forth the Star-spangled Banner, the carillon played it and a fine baritone voice sang it, with the school children joining in the chorus. The other speakers were the writer of this article, who represented the small givers; M. Alfred Rébelliau, President of the International Association, which had done so much for the restoration of the university and its library; M. Georges Goyau, who in the name of university professors of France expressed sentiments of intellectual sympathy and fraternity; Edward Dean Adams, who represented the American engineers giving the carillon; and Cardinal Van Roey, who expressed the thanks of the university.

Following the dedication, a bust of Herbert Hoover, carved by a young Belgo-American sculptor, Suzanne Silvercruys Farnam, was unveiled on the first floor of the new library by Edgar Rickard, on behalf of the Commission for Relief in Belgium. Then came the banquet, which was set in the great reading-rooms of the new library, and at which six hundred guests—half of them American—were present. The occasion was enlivened by renditions of the great carillons, broadcasted from various parts of Belgium and foreign countries, and by a most eloquent toast of welcome and thanks to the United States by Rector Ladeuze. After this the party adjourned to the seats outside and listened for an hour to a marvelous concert consisting of selections on the carillon performed by Denyn of Malines, the most celebrated player in the world, and of songs rendered by a choir from the Royal Conservatory at Liége, directed by the great Gérome. The day closed with fireworks and the illumination of the tower.

Such in brief is the story of the new library dedicated at the University of Louvain. As a matter of fact, the difficulties over the inscription have been

exaggerated. Nothing further is likely to occur. It is natural for some of the more impulsive Belgians, who vividly recall the circumstances under which the University of Louvain was ruthlessly destroyed, to act as they have. But the war is over and should never be revived.

The affair goes deeper and includes far more than a squabble over the form of an inscription. It involves the history of a university world renowned and an intellectual force for a half millennium of civilization. It embodies a substantial expression of sympathy and cooperation from most of the great nations of modern times. It depicts an effort not to forget war injuries, but to rise above them. It repudiates the spirit of hatred and urges us forward toward the attainment of permanent peace and the more complete civilization of the future. As an international event the celebration at Louvain deserves to rank with the conferences at The Hague, Geneva and Locarno, and its underlying spirit matches with that of the World Court, the League of Nations and the proposed disarmaments.

TERMITES AND ARCHITECTURE

By THOS. E. SNYDER

BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE

TERMITES were architects long before the advent of man on earth and their hard earth-like carton or mound nests are built in trees (as lived arboreal man), or in excavations below ground (as the cave man), or as low, hut-like mounds or lofty skyscrapers on and above the ground (as present man). Termites have not only constructed primitive rammed earth or Pieazo and "'dobe" houses but well-ventilated and rain-shedding pagodas (Figs. 1–7).

—Photograph by J. Zetek

FIG. 1. "NIGGERHEAD" ARBOREAL CARTON TREE NEST OF *Nasutitermes ephratae* HOLMGREN, ABOUT 3 FT. × 2½ FT. ON TREE. PANAMA.

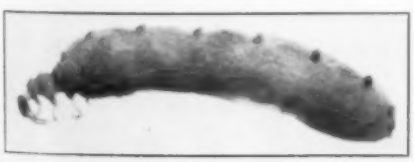


FIG. 2. QUEEN FROM SIMILAR NEST. ABOUT THREE AND A HALF TIMES NATURAL SIZE.

Natives of the Transvaal, South Africa, according to Claude Fuller, have venerated certain termite mounds for hundreds of years; the mounds have remained unchanged through the ages.

With this long experience as practical and successful builders, wood-destroying termites have no difficulty in finding weak points in the construction of the buildings of man. Driven from their homes in the forest by land clearing and civilization, termites have been destructive to man's handiwork. Such ability of termites to destroy is recognized by our colored folk of the southern states who hang "white ants" in a bag around the neck of a teething child to help it "cut" teeth. Did our Negroes bring this folk lore from their original home in tropical Africa, where termites are much more common and destructive?

Aside from the usual destruction of buildings and contents, such as furniture, clothing, shoes, books and paper, timber in contact with the ground, and living vegetation, some odd cases of injury are recorded. Termites are with us both while we are alive and after we are dead. Damage to mummies, coffins in graves, human skulls and bones, ivory elephant tusks, wooden ice houses full of ice, where the woodwork and sawdust insulation were burrowed through, wooden ice boxes containing human cadavers with the strong odor of formaldehyde present, lead-sheathed and rubber-insulated cables in underground wooden conduits, woodwork of wells far below ground, wooden silos and water tanks, the penetration of lime mortar between bricks in foundations and tar and tar paper waterproofing for wood (Fig. 8) have occurred.

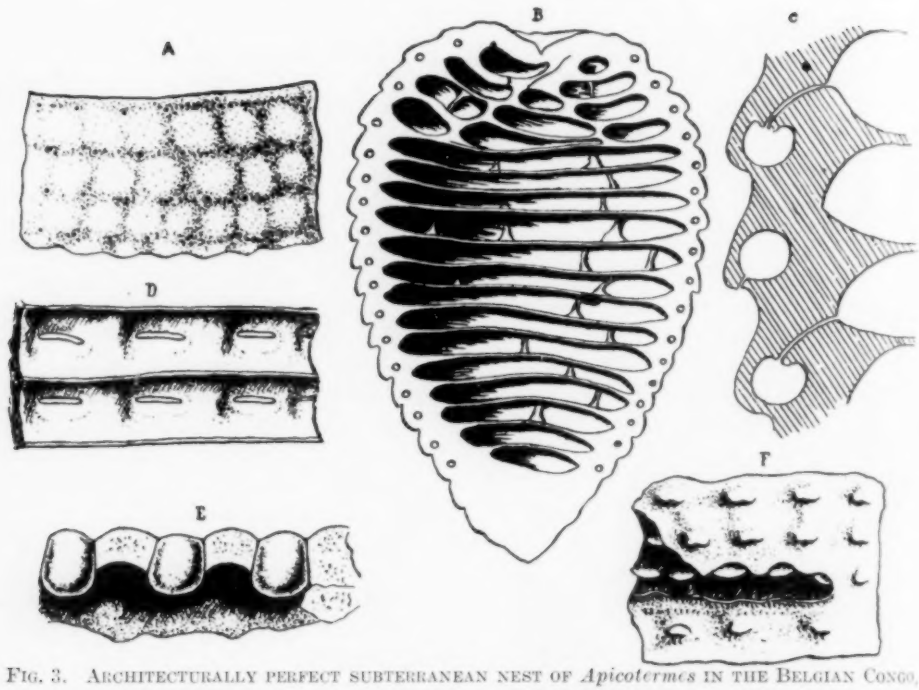


FIG. 3. ARCHITECTURALLY PERFECT SUBTERRANEAN NEST OF *Apicotermes* IN THE BELGIAN CONGO, WELL VENTILATED AND SHINGLED TO SHED WATER. (*a*) PORTION OF EXTERIOR TO SHOW PORES AND MAMMILATE SWELLINGS. (*b*) TRANSVERSE SECTION OF ENTIRE NEST. (*c*) VERTICAL SECTION OF PORTION OF NEST. (AFTER HEGH.)

The chief food of termites is cellulose, which they obtain from both living and dead vegetation; termites are among the few forest insects that attack both living and dead forest trees. In the intestines of most termites are a living fauna and flora of great diversity present in enormous numbers. Protozoa (Flagellates), Amoebae, Spirochaetes and fungi occur. These odd-shaped protozoa contain enzymes which digest the cellulose of wood for the termites; without the protozoa the termites can not live. The rôle of the Amoebae, Spirochaetes, etc., in the intestines of termites is not as well known.

With the clearing of forest land and increasing cultivation of the fields termites or white ants have become increasingly destructive to the buildings and crops of man. The balance of nature has been upset by the destruction of the breeding places of termites in the forest and sodded soil. Greater building operations by man, especially speculative building, has been another factor in the increase of termite damage to buildings.

Owing to lack of information on the destructiveness of our forty-two species of termites or white ants, and their wide distribution throughout the United States, buildings are often improperly constructed and erected with untreated woodwork directly in contact with the ground, leaving the way open for the entrance of subterranean termites.

In consequence of such improper construction, termites burrow into the wood and may greatly damage the woodwork of the building before their presence is detected. It is a great hardship for a man on a moderate salary to make a large initial outlay on a new house and

after one or two years, be forced to expend several hundred dollars additional to reconstruct the building to eliminate termites. The cost of repairing termite damage to buildings and preventing further attack averages from $500 to $2,000, but in some cases is as high as $10,000 to $25,000. Often the expenditure of a few hundred dollars additional during the construction of a building to render it termite proof would save thousands later necessary for repairs.

FIG. 4. EXTERIOR OF ENTIRE NEST SHOWN IN FIGURE 3.

TERMITES IN THE UNITED STATES

Despite popular opinion, practically all the termite damage in the United States is done by native species and such serious damage occurs throughout eastern United States, the Gulf States, Southwest, the Central West and the

—*Photograph by J. Zetek*

FIG. 5. LOW TURRET-LIKE NEST OF TERMITES (*Microcerotermes*) IN PANAMA. (THE WHITE DISK IS A WATCH.)

Pacific Coast. Damage by termites in the "corn belt" is almost as serious as in some of the southern states. Such damage by termites occurs not only in cities but also in rural regions.

Termites of two distinct types occur in this country. Those subterranean in habit burrow through the soil and only

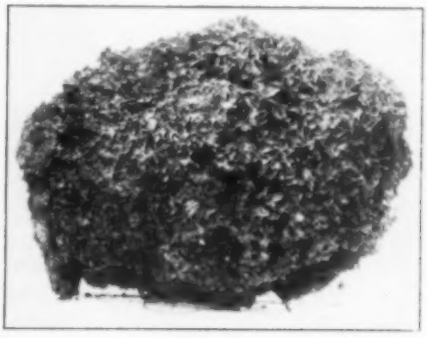
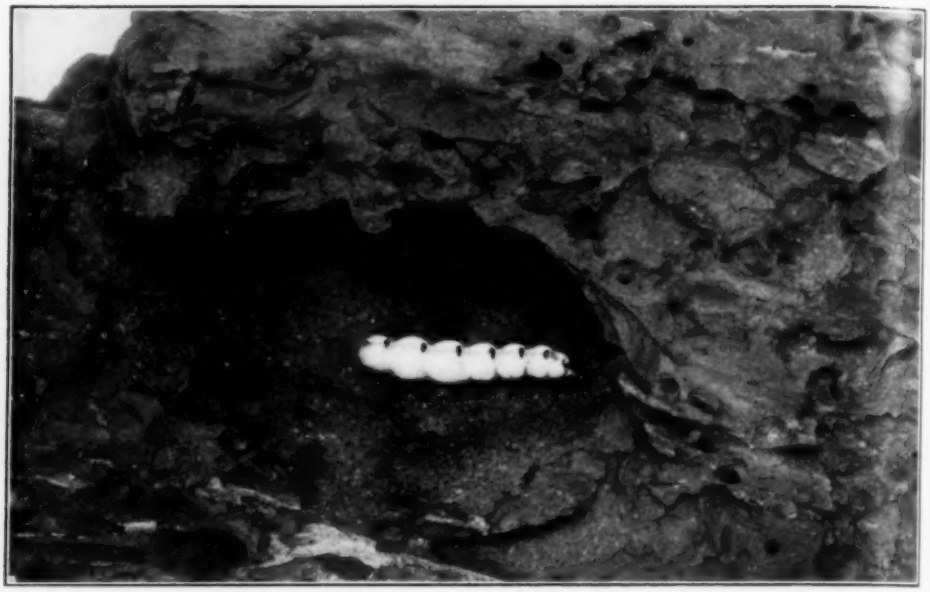


FIG. 6. EARTH-LIKE CARTON NEST ON GROUND OF *Armitermes chagresi* SNYDER. PANAMA.



—*Photograph by J. Zetek*

FIG. 7. ROYAL CELL WITH DEALATED, MACROPTEROUS QUEEN IN CELL OF THE SUBTERRANEAN TERMITE *Microcerotermes exiguus*.

attack wood indirectly from the earth, with which they must maintain contact, to obtain the moisture so necessary to their life (Figs. 9–12). Subterranean termites are widely distributed throughout the United States, over most of which they damage buildings.

Non-subterranean termites never burrow in the earth, but attack wood directly (Figs. 13, 14); they do not require much moisture and will survive in wood with less than the 10 per cent. moisture content of air-dried wood; small pellets of digested wood betray their presence (Fig. 15). These "powder-post" termites are not widely distributed and damage to buildings only occurs in that half-moon of country between a slack line drawn from Norfolk, Va., to San Francisco, Calif.

INSULATION AGAINST SUBTERRANEAN TERMITES

The only effective permanent preventive and remedy is the proper construction of the building with the knowledge of the habits of termites and the specific that will eliminate them. This specific against subterranean termites is "insulation" of all untreated woodwork from contact with the ground; it can be accomplished by the use of stone, concrete or brick foundations and lower flooring or the use of foundation timbers impregnated with coal-tar creosote and metal termite shields. The greatest portion of all termites which damage buildings in the United States is of subterranean habit; if they can be kept from reaching woodwork from the ground they can not survive in the building. Also, if present in a building after all untreated wood, such as joists, wooden floors, sills, etc., has been removed from contact with the ground, they will die out, *i.e.*, dry up, even if the termites have penetrated to the height of several stories in the building. They have been cut off from their moisture supply in the ground, which is necessary for their life.

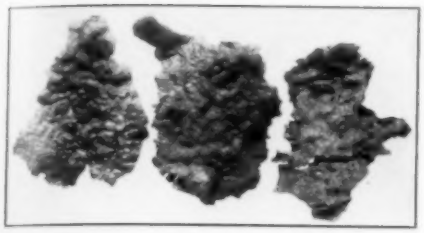


FIG. 8. TAR PAPER AND TAR COATING OF UNTREATED WOODEN TIMBERS LAID IN CONTACT WITH THE GROUND PENETRATED BY SUBTERRANEAN TERMITES.

FIG. 9. TEMPORARY GOVERNMENT BUILDING AT WASHINGTON, D. C., THE FOUNDATIONS AND FLOORING OF WHICH WERE OF UNTREATED WOOD IN CONTACT WITH THE GROUND AND HENCE WERE BADLY DAMAGED BY SUBTERRANEAN TERMITES (*Reticulitermes flavipes* KOL.). IT WAS NECESSARY TO REPLACE THIS UNTREATED WOOD IN CONTACT WITH THE GROUND TO REMEDY THE TERMITE DAMAGE AND PREVENT FURTHER DAMAGE. DURING THE FISCAL YEAR 1926 SUCH REPAIR WORK, NECESSITATED BY TERMITE DAMAGE, COST $140,000 AT WASHINGTON, D. C.

FIG. 10. A CLOSER VIEW OF THE DESTRUCTIVE ACTIVITIES OF THE TERMITES ON THE TIMBERS OF THE BUILDING SHOWN ABOVE.

IMPREGNATION OF WOODWORK AGAINST NON-SUBTERRANEAN TERMITES

Where termites that attack wood directly and not from the ground occur, as well as subterranean termites, it is suggested that only woodwork impregnated with preservatives be used for exterior and interior construction, unless it is impracticable to obtain such treated wood. Buildings should have the doors and windows screened to prevent entrance of the flying adults.

While impregnation with coal-tar creosote is the most effective treatment for foundation timbers to be set in contact with the ground, for interior woodwork and furniture, etc., not in contact with the ground impregnation with zinc chloride, etc., is recommended; wood so treated can be finished and painted.

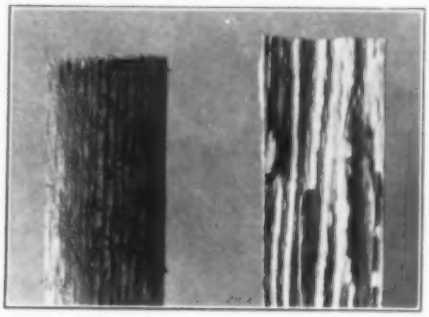


FIG. 11. OAK FLOORING DAMAGED BY TERMITES, UPPER SURFACE NOT PENETRATED, BUT INTERIOR HONEY-COMBED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.).

BUILDING CODE MODIFICATION

In 1923 the first attempt was made to have building codes modified to prevent termite damage and this was made in Burlington, Iowa, where efforts were made to have no untreated wood placed in contact with the ground but that all such timber should be treated with coal-tar creosote.

Recently the Bureau of Entomology of the Department of Agriculture has

been widely advocating the slight modification of the building regulations of various cities so as to include simple rules to prevent attack by these insects. This educational propaganda addressed to city engineers has been conducted with the assistance of the National Lumber Manufacturers' Association, the United States Department of Commerce, Lumber Division of the Bureau of Foreign and Domestic Commerce, the American Wood Preservers' Association and the Associated Press. The National Wood Utilization Commission appointed

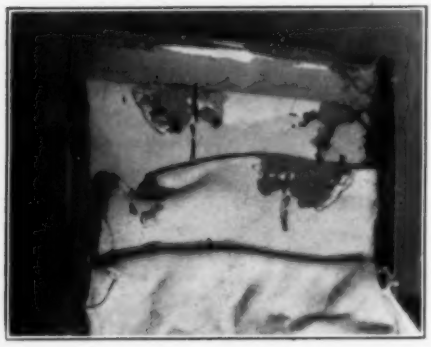


FIG. 12. UNDERWEAR DAMAGED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.) IN AN INFESTED BUILDING IN GEORGIA.

by President Coolidge, with Secretary Hoover as chairman, has an ant-proofing campaign on its program, which will receive early action.

Termite-proofing building campaigns have been advised in certain cities similar to that conducted by the Public Health Service in rat-proofing. Indeed rat-proofing, fire stops and the prevention of decay and insect damage can all be effected by similar methods.

In rural regions, where there are no building codes or chambers of commerce, the educational work can be conducted by prominent citizens with the help of county agricultural agents.

In Honolulu, Hawaii, a million dollars is the annual damage to buildings

FIG. 13. ENTRANCE HOLES INTO WOOD OF NON-SUBTERRANEAN SPECIES OF *Kalotermes*. THESE ARE ABOUT THE SIZE OF BB SHOT AND APPEAR SIMILAR TO THE EXIT HOLES OF WINGED ADULTS OF SUBTERRANEAN SPECIES OF *Reticulitermes*. IN COTTONWOOD TIMBER IN ARIZONA.

done by termites; this city has recently advocated a building code containing fourteen points relating to termite control. Eighty per cent. of the frame buildings in New Orleans have been damaged by termites and 50 per cent. of the business buildings at Pasadena, Calif., some dangerously. Termites annually inflict a million dollars' damage to buildings in Illinois. At Washington, D. C., damage to government and privately owned buildings contin-

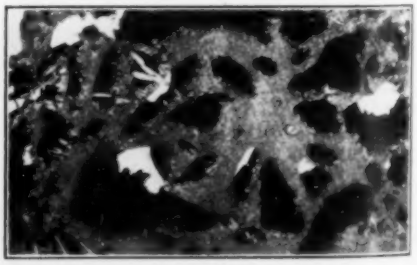


FIG. 14. UNTREATED WOODEN RAFTER IN BUILDING DAMAGED BY NON-SUBTERRANEAN TERMITES. THESE TERMITES ATTACK THE WOOD DIRECTLY AND DO NOT BURROW IN THE GROUND.

FIG. 15. IMPRESSED PELLETS OF POWDERED, PARTLY DIGESTED, EXCRETED WOOD OF NON-SUBTERRANEAN TERMITES; THESE PELLETS FALL FROM WOOD AND ARE AN INDICATION OF INFESTATION.

ues to be serious. Slightly modified building codes for the entire west coast, from Seattle to San Diego, have been considered by the Pacific Coast Building Officials Conference, of Long Beach, Calif. New Orleans has recently adopted termite-proofing measures in its building code. Similar serious damage occurs in southern Florida and in the southwestern states. The aim of the Bureau of Entomology is standardized modified building codes for all the regions where termite damage is serious.

HITS SMALL HOUSEHOLDER

While special effort has been made to protect the small householder from speculative and careless builders many of the more permanent modern buildings are improperly constructed. This applies to some of the government buildings in Washington. With the cooperation of the Superintendent of Public Buildings and Grounds much progress has been made in repairing such buildings and some such work has been done with temporary buildings where practicable.

The use of untreated wood in the foundation of buildings is a great waste of wood, and the replacement cost is often very much greater. A model demonstration termite-proof building has been erected in Canal Zone, Panama, by the American Wood Preservers' Association and associated companies in consultation with the Bureau of Entomology to serve as an object lesson; other similar buildings are to be erected in the United States.

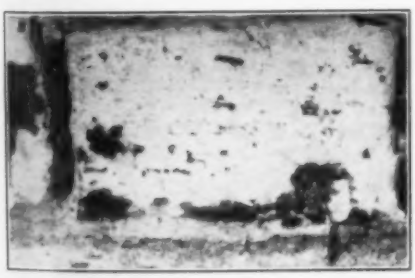


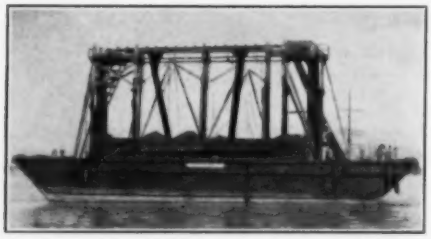
FIG. 16. SUBTERRANEAN TERMITES (*Reticulitermes flavipes* KOL.) PENETRATING LIME MORTAR IN BRICK FOUNDATION OF BUILDING AT WASHINGTON, D. C.

FIG. 17. TESTS OF MORTARS AND CONCRETES AT FALLS CHURCH, VA., TO DETERMINE THE MOST SUITABLE MIXTURES AND METHODS TO PREVENT ENTRANCE BY SUBTERRANEAN TERMITES.

THE MODIFIED CODE

No foundation timbers, floors, sills, clapboard, etc., of untreated wood should be laid on or in the earth, and untreated beams must not be laid in concrete without at least one inch of concrete underneath and separating it from the earth. A special grade of hard mortar (Figs. 16, 17) should be used in making cement for foundations or in cellar walls where they are in contact with the earth, since termites are able to penetrate certain mortars after some

FIG. 18. EARTH-LIKE SHELTER TUBES CONSTRUCTED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.) FROM INFESTED FLOORING OVER UPRIGHT UNTREATED WOODEN TIMBERS AND BRICK WORK IN A BUILDING, SAN FRANCISCO, CALIF.



—*Photograph by Wm. McKay*

FIG. 19. COAL BARGE INFESTED BY SUBTERRANEAN TERMITES IN THE HARBOR AT HONOLULU, HAWAII. SOME DIRT WAS LODGED ALONG THE BOTTOM, BUT MUCH MOISTURE WAS PRESENT. PROBABLY THE INFESTATION OCCURRED BY WINGED ADULTS FLYING TO THIS BOAT. SUCH A BOAT WOULD BE A SOURCE OF DANGER AT PORTS OF CALL WHEN THESE FLYING ADULTS WOULD EMERGE FROM THE WOOD AND SPREAD THE TERMITE. INCIDENTALLY THIS TERMITE (*Coptotermes* SP.) WAS INTRODUCED FROM FORMOSA, JAPAN. REPAIRS COST $5,000.

years' service. For greater safety all brick work extending below the surface of the ground should be faced and capped with concrete at least one inch thick. Metal termite guards should be provided between the earth and treated foundation timbers, stone, brick or concrete foundations. Termites construct over impenetrable substances earth-like shelter tubes (Fig. 18) of small diameter, through which they travel to reach untreated wood. In consequence they can be kept out of buildings by means

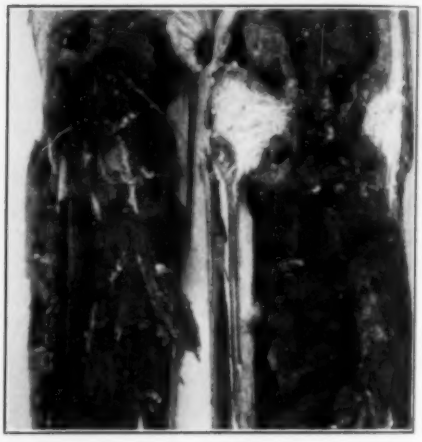


FIG. 20. HEALTHY LIVING SUGAR-CANE KILLED BY SUBTERRANEAN TERMITES (*Reticulitermes* SP.) IN EXPERIMENTAL GREENHOUSE IN VIRGINIA.

of metal barriers. By simply inserting a sheet of galvanized iron, zinc or copper or "termite shield" into the masonry and turning the projecting edges downward at an angle, communication of termites with the earth, where they obtain moisture, can be cut off. In less pretentious frame buildings, metal caps are placed over the tops of construction stone piling or pillars, or wooden supports.

This is a similar method to that used in rat-proofing corn cribs. It is effec-

—*Photograph by G. N. Wolcott*

FIG. 21. THE TERMITE IN ART. AN ARTIFICIAL CARTON TERMITE NEST OF CONCRETE ON CONCRETE ARPOR IN PORTO RICO.

tive and practicable where untreated timber is placed over masonry foundations. These shields need not be unsightly but can be made decorative.

These slight modifications of the building regulations of cities by city engineers would save much property as well as the time and worry to householders. It is a form of house insurance. A prospective home builder should insist on obtaining this safeguard. It will pay in the end.

There are three principal points—insulation of untreated woodwork from the earth, metal termite shields to shut off the shelter tubes and treatment of interior woodwork and furniture with preservatives. The latter recommendation is only essential in the Gulf States, Southwest and southern California

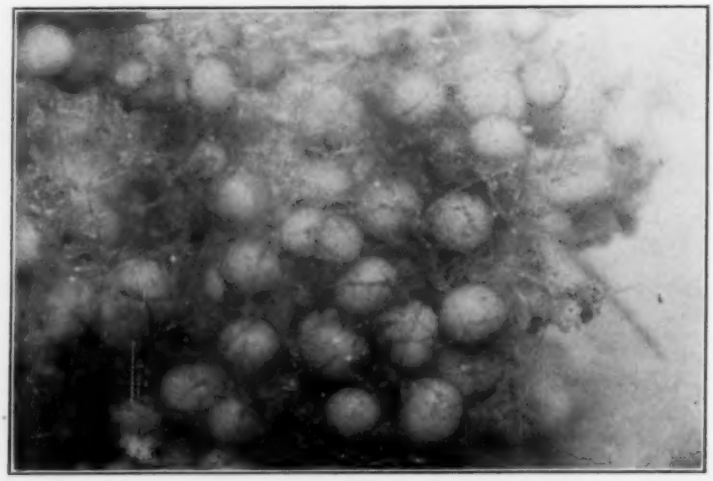
FRESH-WATER SPONGES IN WINTER

By Dr. ANN H. MORGAN

MOUNT HOLYOKE COLLEGE

THERE were nearly twenty animals on one stone—caddis worms, mayflies, water pennies, planarians, Bryozoans and sponges; they were creeping and sprawling, clinging or stuck fast, each according to its kind. Yet it was in the middle of January and the stone had been pulled through a hole in ice which was two inches thick. Even in a shallow brook like that things were far from frozen, and although one animal population had dug down into the bottom, another had stayed up in the water swimming and clambering after food, making nets and waiting for their catch. Most of these were young animals whose rapid growth would begin in February when the early spring food supply became abundant in the brooks. This community in winter resembled a similar one in spring, the bronze copper pennies looked like themselves, only smaller, and the Mayflies were unmistakably like those of April and May. But the winter sponges hinted nothing of their animal relations. They were like so many fig-seeds held to the stone in a bed of bristles. The bristles were the spicules, the skeleton remains of its summer colony, and the seed-like spheres were the gemmules or winter buds of the sponge. Gemmules are little balls of sponge cells, literally samples of sponge, which can grow into a complete colony when there is a proper stimulus from the warm water of spring.

Gemmules may look nothing like sponges, but they will do so speedily if they are given a chance. Those which are shown in these photographs were taken from a shallow brook completely frozen over, in January. They were crowded among the spicules holding them to the stones, and no better picture of clustered fig-seeds could have been wanted. But a lens revealed their



THESE ARE LIVING ANIMALS

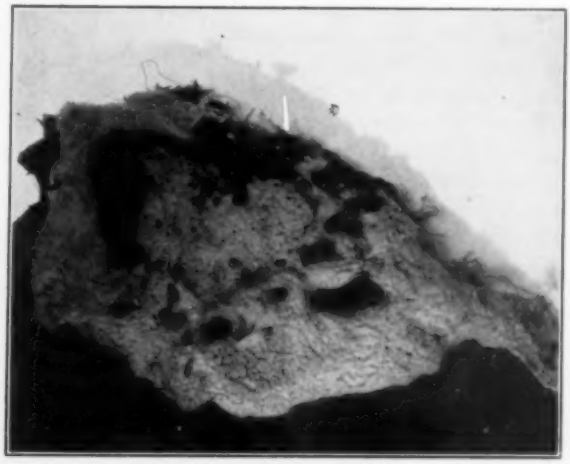
FRESH-WATER SPONGES IN WINTER. MAGNIFIED TWELVE TIMES.

COLONIES GROWING ON GLASS IN JANUARY

THE DARK BODIES ARE THE GEMMULES FROM WHICH THEY HAVE GROWN. MAGNIFIED TWELVE TIMES.

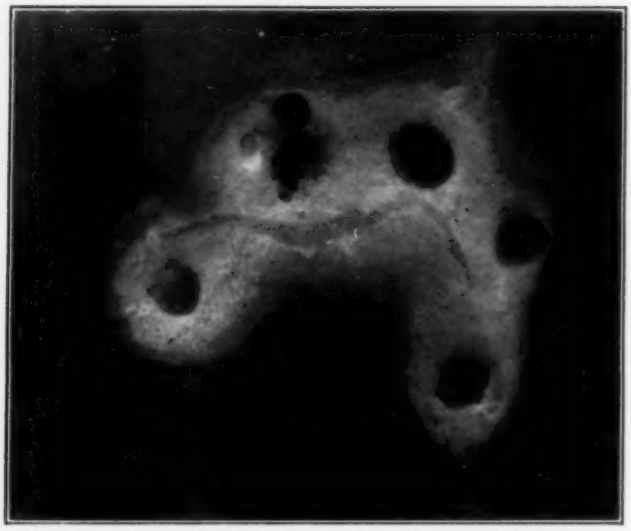
spicule-covered shells with the one small hole in each quite invisible to the naked eye. Some of them were scraped from the rock, taken into the house and put into a dish of water which was set near the window, but outside the path of direct sunlight. Pieces of clean glass were put into the dish, and as the gemmules were dropped down upon them they fell a little distance apart as they are shown in these pictures. For the first few hours they would roll about at the slightest jar of the dish, but within a day or two they had stuck fast. The water was kept fresh and moderately cool, and in three days white plugs were just visible at the holes in the shells which by now had begun to swell and crack open. In another day sponge cells had come through all the crevices and creamy white streams of them had grown down onto the surface of the glass and surrounded the emptying husk of the gemmule.

Five days after the gemmules had been dropped on the glass each hollow shell lay in the midst of a small but flourishing sponge colony with thousands of cells, with true sponge osteoles and gastral cavities. Within a couple of days the transparent borders of the colonies had spread over the surface of the glass and run together so that the gemmule shells were the only signs left of the separate colonies. Several chimney-like pipes had grown upward and had osteoles at their tops, while shorter sacs



SPONGE COLONY

GROWING UPON A STONE IN SUMMER. NATURAL SIZE.



SEVEN DAYS AFTER THE SEED-LIKE GEMMULES WERE TAKEN FROM THE BROOK

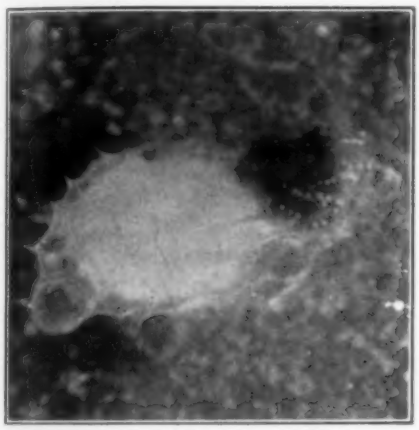
MAGNIFIED TWELVE TIMES.

were stretched thin at their swollen knob-like ends but did not yet have any openings there. Canals and chambers forming beneath the surface began to show as transparent streaks and spots and finally the glass-like spicules began to appear in clusters, visible through a hand lens along the transparent border of the colony. When carmine, a very fine red powder, was scattered lightly over the colony it rested on the surface only a very short time before a few particles of it, probably the very finest, came out on the gentle currents of water which were issuing from every osteole. This too could be seen with a hand lens and was enough to show that the little patch of cells was already carrying on the activities of a sponge. Although it was still smaller than the head of a carpet tack and had been growing outside the gemmule shell for only six days it now both looked and behaved like a sponge colony.

In order to understand either the anatomy or the activities of sponges it would be necessary to study young and full-grown colonies very carefully. Mature fresh-water sponges, such as the common Spongillas, are low cushions of cells whose surfaces are pierced with thousands of minute pores, and with hundreds of larger holes, the osteoles, mounted upon little peaks above the surface level. The pores lead into cavities, the already mentioned chambers first showing as transparent streaks in the sponge. Water is drawn into these so-called dermal chambers and on through minute incurrent canals which carry it into still another series of very small and numerous chambers out of which it passes by other small channels, the excurrent canals. These converge into the gastral chamber from which it is finally passed by way of the osteole to the outside. It was these currents of water from the osteoles that brought the particles of carmine carried through all of these passages after it had been scattered upon the surface of the young colony. Thus water carrying the food and oxygen supply passes in a steady current, as long as the sponge lives, through the pores to the dermal chambers, on through the incurrent canals and the adjoining small chambers through the excurrent canals and into the gastral

chamber to its final exit by way of the osteole.

In summer sponges are much more conspicuous than in winter, but they do nothing which is so spectacular as this burst of growth in the new colony. Fresh-water sponges grow in many lakes and brooks, beneath lily pads, on the undersides of floating sticks and over the stones of brook beds. If the water is muddy or carries a load of dropping particles, their pores become clogged and they are starved and smothered, but clear water bears oxygen to them and



BEGINNINGS OF THE SKELETON

NEEDLE-LIKE SPICULES OF HYDROUS SILICA (OPAL) ON THE EDGE OF THE COLONY. MAGNIFIED TWELVE TIMES.

a sufficient food supply, either dissolved or of microscopic plants and animals. Sponges flourish under these conditions and are abundant in many waters.

Colonies of Spongilla and other common fresh-water sponges often measure several inches in extent, while still others form clumps as large as a quart measure. The Spongillas which grow in direct sunshine are soft green or even brilliant green with chlorophyll, but individuals of the same species hidden beneath rocks or even shaded by brook banks are straw colored or creamy white. The pale ones are more easily recognized as sponges; they are the color of the dried or bleached ones which we are used to seeing; their surfaces are full of holes like bath sponges; they will squeeze dry in the same way and will give off the sulphury smell suggestive of a salt-water sulphur-sponge.

The Spongillas harbor some constant but very inconspicuous visitors, larvae of Spongilla flies which later emerge into the air as four-winged flies. These immature Spongilla flies have long antennae and six legs which readily identify them as insects. They are small, never more than a quarter of an inch long. They are yellowish green with faint dapplings of brown on their backs and with little bristles sticking out from their bodies. Bits of debris and broken sponge catch upon these bristles and hide the shape of their bodies. Being hidden in all these ways they also eat the sponge tissue; they fill their food canals full of it and so become literally sponge colored inside as well as outside. No one could want a more convincing camouflage than a young Spongilla fly which has eaten its way down into a sponge. It may be resting there with its whole length in full view, but be quite invisible even to careful scrutiny through a lens. It is only when it clambers over the sponge that it may be caught, and even then it is much more like a piece of sponge on legs than like an insect.

In early fall the Spongilla colonies, like the rest of the fresh-water sponges, begin to shrink and shrivel away. By October and November many of the cells have died and the spicules are left bare. But other cells have been drawn together in closely packed balls and have secreted a protecting crust about themselves. They have become the gemmules or the winter buds. These gemmules are the winter representatives of fresh-water sponges, and are seed-like in their looks and behavior; like seeds they can endure hard weather, but are so sensitive to changes that they will start to grow with any encouragement from warmth and fresh water.

CLIMATOLOGY AND SOME OF ITS APPLICATIONS[1]

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Meaning and Scope of Climatology

The word *Klima* (derived from Κλινειν, to slope or incline) as used by the Greeks, doubtless originally had reference to the angle of the sun's rays. It was, at first, simply a mathematical or an astronomical term, not associated with any idea of physical climate as we use the word to-day. An excellent illustration of the ancient meaning of *Klima* is found in the system of *climates* proposed by the famous geographer, Ptolemy. This was a division of the earth's surface between equator and north pole into a series of *Klimata,* or parallel zones, separated by latitude circles and differing from one another simply in the length of the longest day. A change of one's *Klima* in those days simply meant a change of latitude. Such a change of position on the earth's surface was, however, gradually seen to mean a change in atmospheric condition as well as in the length of day. Thus *Klima* came to have its present meaning. Even in their own country with its rugged topography the Greeks surely observed in very early times that southern slopes or exposures have certain climatic advantages over northern slopes. The conception of *Klima* as merely indicating the inclination of the sun's rays must therefore inevitably soon have been given up in favor of the larger definition. *Climate,* as we now use the term, is the sum-total of the weather phenomena that characterize the average condition of the atmosphere at any place on the earth's surface. What we call *weather* is merely one phase in the succession of phenomena whose complete cycle, recurring with greater or less uniformity year by year, makes up the climate of any locality. Weather changes; climate does not. *Climate,* then, is average *weather.* It is the sum-total of all the weather. Climatology is the study or science of climates.

There is much misuse of the terms weather and climate. To illustrate, we can say, "The weather in Boston was rainy in May, 1928," or "The weather was cool in the early part of June, 1928." We can also correctly say that the "winter climate of New England is cold and snowy," although January, 1928, may have been relatively warm and "open." It is, however, incorrect to say, "The *climate* of Boston was cool and rainy in May, 1928." As soon as we speak of the atmospheric conditions of a single period of time, we must use the word *weather.*

Relations of Meteorology and Climatology

Meteorology and climatology are interdependent. It is impossible to distinguish sharply between them. Each needs the results obtained by the other. Meteorology is the more comprehensive term. It is the science of the whole atmosphere. Meaning, literally, the discussion or description of things suspended, or supra-terrestrial, it originally, as in Aristotle's first treatise on meteorology, included within its field not only the atmospheric conditions to-

[1] Introductory lecture in a course on "Man and his Climate," given before the Lowell Institute, Boston, November 19, 1928.

day associated with that science, but also stars, comets, meteors, earthquakes, auroras, the composition of matter and other subjects as well. In a strict sense meteorology now deals with the physics of the atmosphere. The study of meteors, except very indirectly, does not fall within its field. Meteorology considers the various atmospheric phenomena individually, and seeks to determine their physical causes and relations. Its view is largely theoretical, yet one of its main aims is to be of service to man. The aspect of meteorology of the most immediate, practical, everyday importance to man is that which concerns weather forecasting. In the synoptic daily weather map the unit of time is the essential thing, the observations on which the map is based all being made at the same time.

When the term meteorology is used in its broadest sense, climatology is a subdivision of meteorology. Climatology is largely descriptive. It aims to give as vivid a picture as possible of the interaction of the various atmospheric phenomena at any place on the earth's surface. Its unit is therefore place, while, as just stated, time is the fundamental unit in meteorology. The business of the weather forecaster is to predict tomorrow's weather, as well as he can in the light of our present knowledge. The climatologist, on the other hand, tells us in terms of averages what the general or normal atmospheric conditions in any locality are likely to be at any season or in any month, as inferred from past experience. This is in no sense a long-range forecast. It is simply a picture of what, under normal conditions, may reasonably be expected. Climatology rests upon physics and geography, the latter being a very prominent factor. Climatology may perhaps well be defined as geographical meteorology. Its main object is to be of practical service to man. Its method of treatment lays most emphasis upon the elements that are of most importance to life. Climate and crops; climate and industry; climate and health, are subjects of vital interest to man. Few sciences concern man more intimately in his daily life. It is immediately practical, of vital interest, and intensely human in all its applications.

Climatology Rests Upon Meteorological Data

Scientific climatology is based upon numerical results obtained by systematic, accurate and long-continued meteorological observations. It deals with the same groups of atmospheric conditions as those with which meteorology is concerned, viz., temperature, moisture, wind, pressure, evaporation, and so on. The characteristics of each of these so-called *climatic elements* are set forth in a standard series of numerical values, based on the day-by-day meteorological observations, corrected and compared by well-known methods. The official meteorological services all over the world give a large part of their time to the collection of climatic statistics, a function universally recognized as of equal importance with the daily weather forecasts. These statistics are indispensable in medicine, in biology, in engineering, in agriculture, in transportation and in many other branches of science and industry. Every person who carefully records an extended series of accurate meteorological observations potentially contributes to a better knowledge of the climatology of his country. American climatology really owes its beginnings to the pioneers who, alone and with inadequate facilities and equipment, faithfully kept their daily records in the earlier years of our country's history. Names that may well be remembered are those of the Reverend John Campanius, who in 1644–45, at the Swedes' Fort, near Wilmington, Delaware, kept what

is believed to be the first regular record of the weather on the North American continent; of the Honorable Paul Dudley, Chief Justice of Massachusetts, who kept a meteorological record at Boston in 1729–30; of Dr. John Lining, who began thermometer records at Charleston, South Carolina, in 1730 and maintained a more extended series of observations from 1738 to 1750; of Professor John Winthrop, of Harvard College, who from 1742 to 1778 kept regular weather records at Cambridge. It is not irrelevant to mention that Thomas Jefferson at Monticello and James Madison at Williamsburgh, Virginia, made "a series of contemporaneous observations" during the period 1772–77, which "showed that the climatic peculiarities of those two places harmonize completely."

It is the responsibility of the meteorologist to take the regular daily routine observations upon which, eventually, the structure of climatology is built. Every day, year in and year out, all over the world, on land and at sea, thousands of meteorological observers are patiently reading their instruments and recording their data for the future use of their fellow-men. As another has well expressed it, "the meteorologist's business is to make the bricks as perfect as he may, whatever the use to which they may be put. The climatologist, the biologist, the geographer, are the builders who must have sense and knowledge to use them."

Climatology a Science of the Future

So far as extreme accuracy of its data is concerned, climatology is inevitably to a considerable extent a science of the future, for the longer the series of observations, the more accurate are the results. Climatic tabulations necessarily quickly go out of date. Each year, each month, indeed each day, produces additional observations and thereby brings the averages closer and closer to the desired degree of accuracy. It is, therefore, with a relatively young science that we are here dealing. Climatology will grow as additional data accumulate concerning the atmospheric conditions in all parts of the world, and especially as observers in the thinly-settled and backward districts increase in number. It is a rather discouraging sentence which one of my English colleagues wrote a few months ago: "We shall never accurately know the distribution of the annual means of the meteorological elements over the world." In a sense this is, of course, true. But the degree of our discouragement with this situation will depend entirely upon our interpretation of the word "accurately" in the statement which I have just quoted. Absolute perfection of accuracy we can not hope to attain within any period of time that has any real interest to those of us who are living to-day. But accuracy sufficiently great to make our present knowledge of the world's climates of immense and immediate practical importance to man we have already attained. Is not the object of attaining ever-increasing accuracy the real inspiration and incentive of all our pursuit of knowledge?

In the fact that climatology is so young a branch of science we may, I believe, find the explanation of its rather scanty *general* literature. Its students have been so busy collecting and summarizing observations that there has been little time left over for the discussion of general principles and laws.

Summarizing Climatological Observations

Climate concerns first of all the *average* conditions. But *means* may be made up of very different values of the elements that go into them, and therefore a satisfactory presentation of a climate must include more than mere averages. It must take account, also, of

regular and irregular daily, monthly and annual changes, and of the *departures*, mean and extreme, from the average conditions which may occur at the same place in the course of time. Further, a determination of the frequency of occurrence and of the probability of occurrence of a given condition or of certain values of that condition is often of very great economic importance. Levees should be built to resist the *highest* floods; water-pipes should be buried deep enough to be safe from freezing in periods of *greatest* cold; buildings and bridges should be strong enough to withstand the *highest wind* velocities; gutters and sewers should be planned to take care of more than "average" downpours. Again, the frequency of occurrence of certain conditions, as, *e.g.*, of temperature changes of 25° or more, or of temperatures over 100°, or below, say, −40°, may be a very important item of information in certain climates. Similarly, especially for the farmer, the probability of occurrence of killing frost during a critical time in the growth of certain crops, or of rain during harvest time, is a significant part of practical climatic information. Or, to state it in very general terms, the more detailed is the available information about a climate, the greater is the value to man.

The first stage in climatological research is to bring together, correct, standardize and tabulate all the available meteorological observations. This requires patience, accuracy and enduring enthusiasm for a very fatiguing and monotonous task. "Pure" climatology concerns itself with the preparation of the numerical data. The second stage—and one that is naturally more interesting and more inspiring—concerns itself with the applications of these numerical results to the life and activities of man. That is the real aim and purpose of climatology—"pure" climatology is then superseded by "applied" climatology.

In order that I may indicate to you some of the innumerable ways in which our science is applied in the service of man, I have chosen a few examples, obvious, simple and doubtless to some extent already more or less familiar to you.

Let us take first a few cases from the border-zone between climatology and botany. After that we shall select other illustrations, from engineering, from insurance, from geology and from military science.

A map of the natural vegetation of the world is fully intelligible only when studied in connection with the distribution of rainfall and of temperature. There are, as is well known to all of you, three major zones or belts of natural vegetation: forests, grasslands and deserts. Each of these belts is broken up and modified, in a more or less irregular way, by the topography; the presence of mountains, plateaus, lakes and rivers, as well as by differences of soil and other controls, so that often the map of natural vegetation becomes a patch-work rather than a simple zonal sequence of forest, grassland and desert. Furthermore, man has himself very greatly changed natural conditions by cutting down forests, planting crops and irrigating deserts. In spite of all these modifications and changes, certain broad climatic controls remain and can easily be stated. Thus, palms, which may be taken in a general way as the typical trees of the tropics, are fairly closely limited in their natural extension into the higher latitudes of the temperate zones by a temperature of 68° F. for the average of the year. Indeed, so striking and so critical is this control that the line of 68° mean annual temperature has been generally accepted, certainly among climatologists, as the most logical boundary between the temperate and the tropical zones. Again, as we progress poleward from the temperate zones toward the Arctic or Ant-

arctic, it is found that the temperature of 50° F. for the warmest month of the year is a critical one. A line connecting all places that have this temperature runs around the world in a somewhat irregular course, bending poleward or equatorward according to the conditions of land and water and altitude, but in general marking fairly closely the polar limits of tree growth and of agriculture. For this reason climatologists have selected this isotherm of 50° for the warmest month as being the most logical boundary between temperate and polar zones.

The world's forests grow where the rainfall is fairly abundant and where the temperatures are not too low. Mean annual rainfalls ranging between 100 inches, or even more, and about 20 inches, are seen to occur where forests grow, the need of moisture being greater where the temperatures are higher and the evaporation is consequently increased. Grasslands are found with mean annual rainfalls of about twenty to fifteen inches, while semi-deserts or deserts are associated with rainfalls of ten inches or less a year. The foregoing are very broad generalizations. Forests are broken by grasslands; grasslands are interspersed with forests where the rainfall is more abundant and soil and other factors are favorable; plateaus and mountains in deserts, rising as islands of heavier rainfall, carry trees and become the sources of streams that flow down into the desert, providing water for local irrigation and for tree-growth —welcome oases for desert travelers. The life of primitive man is very largely controlled by the type of vegetation by which he finds himself surrounded. From it he secures much or all of his food; it provides him with raw materials; it largely determines his occupations; it supplies his clothing.

As my next illustration of an intimate and critical control of a specific climatic condition over man's use of the earth's surface, I have selected the mean annual rainfall line of twenty inches in our own country. I know of no more striking example anywhere in the world of the economic and historical importance of one specific climatic factor in the life of man.

The United States may conveniently be divided into two major divisions, separated by a transition zone lying in a general way along the 100th meridian. This meridian, running north and south, passes about centrally through North and South Dakota, Nebraska, Kansas and then continues southward across Oklahoma and Texas. The line marking an average annual rainfall of twenty inches roughly follows the 100th meridian. The eastern half of the country has sufficient rain in normal years, and produces crops cultivated by ordinary farming methods. To the west of the twenty-inch rainfall line there is a vast region where agriculture of the type characteristic of the rainier east is as a whole no longer found (except on the northern Pacific coast and in parts of California and of the northern Rocky Mountain district); where water, not land, is the measure of success. By climatic limitations, dry farming, grazing and irrigation are man's three methods of making use of the land—dry farming where the rain is most abundant; stock-raising where there is not enough moisture even for dry farming; irrigation over the limited areas where water is available. "Dead line" was the name given to this critical boundary in the early days. "East of it lies success," as the saying went, "west of it failure. Look out for the 'Dead line.'" Once the home of immense herds of bison which pastured on the natural grasses; then browsed over by millions of cattle; afterwards, in the days of the "boom" of the later eighties and even more recently, the scene of unhappy and

disastrous attempts to use them for large-scale agricultural operations of the eastern type, the natural limitations of the Great Plains have come to be fully recognized. They were never fitted to be a region of vast farms for raising crops by methods that take no account of the special climatic and soil limitations. They could not continue to support vast herds of cattle which exhausted the natural pasturage and perished in great numbers during dry seasons and in the severe winter cold and storms. They are available, here for dry farming; there for local irrigation from streams or wells, with small individual farms and cattle ranches; elsewhere, again, for grazing.

It gradually became clear that in many sections immense herds of cattle, roaming more or less at will and suffering heavy losses, were becoming less profitable than smaller herds, kept and bred under more careful supervision and provided with some forage in addition to that supplied only by the natural range. Local irrigation led to the development of small farms, with intensive cultivation of many general farm crops. The great cattle ranches of wealthy owners or of corporations have become less numerous, and the smaller holdings of individual farmers who combine stock-raising with the raising of varied crops and of feed for the cattle have increased. The whole history of this great region is one of an increasing adjustment on the part of man to his climatic environment and a recognition of the climatic handicaps.

I have referred to dry farming and to irrigation as characteristic and inevitable aspects of our dealing with much of that vast area west of what used to be called the "Dead line." Dry farming is farming without irrigation where the rainfall is too small for agriculture unless this rainfall is cared for and conserved in a special and peculiar way. The problem is essentially climatic. Dry farming is of such a comparatively recent date in this country that there are a good many questions regarding it which time alone can answer. One thing is certain. There is a pretty definite limit to the amount of land that can be irrigated. Water is not available for any more. As to the lowest mean annual rainfall limits for profitable dry farming in the western United States, I can not give an exact figure. Perhaps from ten to twelve inches would be a fair estimate, but there are exceptions to this rule. Where the mean annual rainfall is over fifteen inches, dry farming is generally practiced only where the distribution of the rainfall through the year is unfavorable or where evaporation is large. To quote a fair and conservative opinion of another, dry farming in many sections of the United States "has not been tried through a long enough period to make sure that it is more than a precarious occupation, sometimes profitable, occasionally disastrous; it is invited more by the low price of arid lands than by the certainty of crops; it can be best practiced by those who have enough hope or capital to survive one or two years of failure with two or three of success." "If you *can* irrigate, irrigate. Where you *can not* irrigate, practice dry farming," is good advice west of the "Dead line."

Irrigation is an expression of man's dissatisfaction with the amount or the distribution of rainfall. It is initially and fundamentally a climatic problem. Where irrigation is practiced, a wide range of crops can be raised, determined by local conditions of climate, soil, topography and demand. Irrigation means high price of land, relatively small holdings and a high degree of local cooperation. Being an expensive type of agriculture, it is to a large extent dependent upon economic controls.

Conditions in the west have gradually settled down to a reasonable adjustment on the part of man to the available water supply. It is now clearly recognized that the water available for irrigation is very limited, for it is obvious that all the water used in irrigation must have fallen somewhere as rain or snow, and precipitation over most of the far west is small at best. Most of the "Great American Desert," as it used to be called, must forever remain non-agricultural. But careful study of all possible sources of water supply will result in further extension of irrigation enterprises over limited districts that are today producing nothing but sage-brush and other natural types of arid-land vegetation. It has been estimated by competent authorities that if all available sources of water supply were fully utilized the potentially irrigable land in the west would amount to about double the present area of irrigated land. It is to be noted, however, that the cost of construction of irrigation works increases as less and less favorable projects are developed. The cost of land under the ditch and ready for farming may exceed the demand at the prices quoted.

To a superficial observer of our western "deserts" it seems as if irrigation must completely and successfully solve man's agricultural problems there. But here, as everywhere, the apparent solution of one problem gives rise to other new and unexpected problems. Nowhere is there a lack of struggle. When the ground-water level rises as the result of irrigation it causes a deposit of alkaline salts on the surface. Thus the irrigated desert has in places become an alkaline desert. The irrigation canals are bordered by weeds. From these, seeds drop into the water and are distributed over the fields and through the orchards, giving rise to another new problem. Thus the eternal struggle of man against nature goes on in varying phases.

Striking illustrations of practical studies of climatology in the service of man are found in the extension of the areas devoted to rubber and to cotton. Brazil for many years dominated the world's rubber markets. In the hot, damp Amazonian forests, *Hevea brasiliensis*, the Para rubber of commerce, found its natural home in a congenial tropical climate and in rich deep soil. From those vast forests, exploited by what in reality amounted to slave labor, came most of the rubber used in the United States and Europe. As far back as the later seventies, with a keen sense of commercial rivalry, England imported some seeds of the best Brazilian rubber trees to Kew Gardens, where they were carefully planted and developed. A study was then made of the climates of the British Far Eastern possessions, in order to find conditions of temperature, rainfall and soil most suitable to the establishment and extension of rubber plantations. Experimental plantings were undertaken. The intensive studies of the authorities of Kew Gardens—a beautiful example of an investigation in economic climatology—met with success. Brazilian rubber trees were introduced into Ceylon and the Malay Peninsula and Archipelago. "Tame" rubber gradually replaced the "wild" Brazilian rubber. Brazil lost her control of the world's rubber markets. The rubber plantations of the Far East, British and Dutch, now contribute nearly all of the rubber of commerce. It is not surprising that Great Britain developed the "Stevenson Plan," about which so much has been heard, to enforce the restriction of the rubber output in British possessions. This plan seems to have given rise to difficulties common in artificial attempts to regulate the laws of supply and demand, and the announcement of the abandonment of the scheme has not been a surprise. With the changing conditions in the Far East, the recent purchases of vast tracts favorable for

rubber cultivation in western equatorial Africa by the Firestone interests, and in Brazil by Mr. Henry Ford, it is clear that the rubber market is likely to undergo uncertainties and fluctuations in the near future. Further, several intensive climatic studies are being carried on in our own country with reference to the planting of selected varieties of trees or plants capable of supplying rubber, or at least substitutes for rubber, for use in certain branches of industry. In the Philippines, also, the development of rubber plantations is receiving increasing attention. There are doubtless considerable tracts in those islands suitable for rubber cultivation, provided labor and other difficulties can satisfactorily be overcome. It would seem, however, as a general proposition, that in the long run it will probably not be wise to undertake rubber production in the latitudes subject to typhoons, whose high winds are often very destructive to trees. I suggest, therefore, that the latitudes nearer the equator than about 10° N. are likely to be safer than higher latitudes within the so-called typhoon belt.

Another case of the application of climatological study to the extension of the area now occupied by an important commercial plant is that of cotton. Here again scientific and commercial sense have combined in an interesting way. The question for Europe has for years been: "How can we become independent of the United States in the matter of cotton, and also increase the area devoted to cotton-raising in order to supply the world's growing demand?" The American Civil War really started this movement, but the foundation of the British Cotton-Growing Association in 1902, and of similar organizations in France and in Germany, has opened a new chapter in this discussion. The British Cotton-Growing Association has been the motive power behind intensive studies of the possibilities of cotton-growing in countries under the British flag, and has carried through some excellent pioneer work in economic climatology, especially in Africa. Distinct success, or at any rate a fair degree of success, has been attained in parts of the Sudan, in western Africa, in Uganda and Nyasaland, in South Africa. The World War seriously interfered with these undertakings, and problems of labor, transportation and general financing have been serious handicaps to large developments. The British Cotton-Growing Association has also promoted cotton cultivation in India, and has increased the acreage in the West Indies. Other European countries have also taken part in this general movement.

South America offers a field for the extension of cotton-growing. From the necessarily very superficial study which I was able to make in certain parts of South America some years ago, I believe that the rather limited irrigated districts of Peru, now, and for many years back, devoted to cotton, can be considerably extended; and that Brazil, which had a distinct "boom" in cotton during our Civil War, can not only come back to its then acreage but even greatly increase it. The northern portion of the Brazilian plateau, south of the Amazon forests, seems to offer conditions of climate and soil which are favorable. There are no, or but very rare, frosts; no severe storms; abundant sunshine, and enough rainfall in normal years. Some years ago the Argentine Ministry of Agriculture had a study made of the northern Argentine provinces, and reported that most of the lowlands in that section of the country, and the valleys not above 1,000 meters in elevation, are suitable for cotton cultivation both as regards climate and soil. Probably, also, neighboring portions of Paraguay and the eastern Bolivian valleys may eventually prove suitable for cotton. But little of the Guianas is adapted for cotton-rais-

ing, and while the Valencia district of Venezuela produces a little cotton now, there seems little likelihood that there will be any great extension of the acreage devoted to cotton-planting in that country.

I would not be misunderstood in my prediction as to the future for cotton in South America. There are many very serious difficulties in the way of any rapid development of this undertaking, such as problems of an adequate labor supply, of transportation, of financial organization, and the like. Cotton-growing is very much more than a question of climate alone. There can not possibly be any rapid development, but it may not be too optimistic a view to expect in the future a considerable increase in cotton acreage in the districts I have mentioned. The day may not be so very far distant when South America may take a more important position in the world's cotton markets than it does to-day. Certain portions of Australia, also, where there is sufficient water, either supplied by the natural rainfall or obtained through irrigation, seem well suited to cotton-cultivation, which may in the future be considerably developed there.

Let us turn now to a wholly different aspect of the use of climatic data in the service of man. One of the most striking developments in the insurance business in the United States in the last few years is the very rapid increase in weather insurance of all kinds. We are all perfectly familiar with insurance against fire resulting from lightning, and perhaps also with that against damage by high winds. But less familiar, because less common, is insurance against damage by hail, by frost, by drought, by floods, by tornadoes. In Europe this whole business of insurance against weather risks is fully stabilized. It has for years been customary in England, for example, to take out insurance against loss of gate receipts on account of rain at cricket games and outdoor pageants. In this country this class of insurance is rapidly becoming popular. We insure motion picture companies against lack of snow if the picture is to be made as a snow scene; the proprietors of summer hotels and amusement resorts can insure against rainy week-ends; building contractors against loss of time resulting from unfavorable weather. A few years ago the Harvard Class Day Committee, for the first time, took out rain insurance for Class Day. Another very interesting recent development is insurance of eclipse expeditions against cloudiness during the eclipse. And so on.

It is clear that insurance is a necessary and legitimate business, that it should be conducted on such lines as to compensate the insured against loss in return for a reasonable premium, and should at the same time result in fair profits for the companies concerned. One of the difficulties in connection with some of the new forms of weather insurance is that the companies often have an insufficient knowledge of the climatological conditions and of the actual risks involved. Hence, premiums may be unreasonably high. The business is not yet stabilized. A good illustration of this situation, now rapidly being remedied, is the case of tornado insurance in the United States. Much tornado insurance used to be handled by farmers' mutual insurance companies, which distributed their risks without proper regard to the habits and characteristics of tornadoes. These violent whirling storms—the most intense atmospheric phenomena with which man has to contend—practically always travel in an easterly or northeasterly direction. Their path of destruction is very narrow—usually about a quarter of a mile wide. Now it is obvious that tornado risks should not be distributed in an easterly or northeast-

erly direction, for a tornado may wreck everything along that line. The risks should rather be distributed in a northwest-southeast direction. Then, if a tornado occurs, the damage done will be on a narrow path *across*, and not *along* the line of the insured buildings; a single company is extremely unlikely to suffer a very heavy loss, and the distribution of the risks is in accordance with the known facts of tornado occurrence.

In this whole matter climatology has much to offer in the service of man. What the insurance companies and those who insure need to know are the detailed facts concerning the distribution of the weather phenomena and the climatic conditions which are unfavorable. Thus, if we wish to insure gate receipts against loss because of a rainy day, we should know the probability of rain at the place and time in question. We should know at what hours the rain is most likely to come, and whether it will probably be heavy or light. Frost insurance, scientifically managed, requires information concerning the probable dates of first and last frost; the possible departures from those dates; the frequency of killing frost in the frost months, and so on. Tornado insurance should rest upon a full understanding of all that is now known concerning the distribution of tornadoes in place and in time, the location of the so-called "tornado belt," the districts either wholly free from those violent storms or only at very long intervals subject to them.

These few examples will indicate what is in my mind. Climatology is ready, and anxious, to put at the service of insurance companies all that is known concerning weather and climate. From climatic tables already available any one who is interested can inform himself as to the average conditions of rain, snow, frost, thunderstorms, tornadoes, gales, and so on, which may be expected in normal years. This information is in no sense a long-range weather forecast, as I have previously pointed out. But it does give a fair idea of the weather insurance risk under normal conditions, and is a sufficient basis for writing such insurance in a way that shall be fair both to insurer and insured.

Climatology, then, is ready to give all possible information and assistance to the insurance companies in this matter. On the other hand, also, weather insurance is stimulating climatological research. Thus, in the single item of the hourly distribution of rainfall alone, a bit of information of very great significance in rain insurance, the demand of the insurance companies for this information has resulted in the undertaking of numerous studies of this particular aspect of rain and snowfall. Our general climatological knowledge has already been distinctly improved and made more complete by this new development of weather insurance. And this mutual cooperation is but beginning. I look forward to a distinct advance along these lines, for the common advantage of the science of climatology on the one hand and of the business of insurance against weather risks on the other.

So many engineering problems concern outdoor construction and operation that weather and climate are necessarily critical factors. Buildings must be constructed to withstand the maximum wind pressure that can ever occur. Bridges across rivers must be firmly anchored on piers that can not be carried away during the greatest floods. If built across what are usually dry canyons in the mountains of arid regions, it must be remembered that sudden "cloud-bursts" are characteristic of such localities, bringing downpours which may fill these narrow valleys to a depth of many feet of water in a very short space of time. In railroad construction through mountains

where heavy snowfalls and avalanches are known to occur, special provision has to be made on this account. The famous "Forty Miles of Snowsheds" on the Southern Pacific Railroad where it crosses the Sierra Nevada Mountains between Sacramento and Reno are a striking illustration of the way in which railroad engineers have to meet climatic handicaps. These sheds must be able to support the maximum weight of snow that may fall upon them. Further, the danger from fire is so great that watchmen have to be kept constantly on guard, especially in the dry season of summer, and trains equipped for fire-fighting are in readiness for immediate use. All this adds greatly to the operating expense of a railroad. On one of our eastern railroads, a few winters ago, snow removal after one heavy snowstorm cost $25,000 for each inch of snow that fell. This sum included the actual work of snow removal, and also the extra motive power, the cost of demurrage on freight cars and other similar expenses.

Before undertaking any irrigation enterprises, as in our own arid or semi-arid west, it is essential to have a very accurate knowledge of the amount of the available water supply. To secure this information, rain-gauges must be installed on the watersheds, and, as in many parts of the west, surveys must be made of the amount and character of the snowfall, whose melting supplies most of the water used during the spring and summer months. It is sheer folly to spend money in constructing dams and reservoirs if the available water supply is to prove inadequate, or if the amount of water is ever to be so great that dams will burst under the pressure. For most of the important snow-fields in our western mountains there is already available sufficient information on this point to serve our present needs, but as the demand for more irrigation becomes increasingly insistent in the years to come further data must be secured. The heavy snows of the Sierra Nevada Mountains in California have well been called "the life-blood of the state," and those who have visited California have enjoyed what the melting Sierra snows provide.

No modern city water supply is planned without a very thorough study, extending over many years, of the rainfall over the area where the reservoirs are located, and no one watches more carefully the amount of precipitation from day to day, and from storm to storm, than he who has charge of a great city's water-works.

A very recent illustration of the importance of a thorough study of local weather and climate is seen in the preliminary stages of the establishment of air-ports. After the World War the story leaked out that during the war an army air-port was established, necessarily very hastily, somewhere in the British Isles. No adequate preliminary study of local weather was made; thousands of pounds were spent in the preparation and equipment of the air-port; but the location proved wholly unsuited to its intended use because of the erratic and dangerous character of the winds. This matter is now managed very differently. I happened to be in San Francisco last June, and while there I made inquiries concerning the new municipal air-port. The city for a year employed two expert meteorologists, loaned by the Government Weather Bureau, who made a very thorough survey of the atmospheric conditions in the locality where it had been planned to establish the air-port. This survey included the upper-air conditions, as determined by means of free balloons, as well as the surface conditions. The work has been completed, and the report has been written. Thus, in connection with the rapid development of flying in all its aspects, climatology is already

making important contributions, and will increasingly prove its helpfulness in making aviation safer.

An architect came to me a few years ago and asked me to tell him exactly what he should plan for in building roofs so that they would support the greatest weight of snow that might ever rest upon them. The question was a reasonable one, but the answer was not quite so easy to give in the precise figures that were desired. Our ordinary numerical data on snowfall include the mean annual and mean monthly depth of snow, the number of inches on the ground at the middle and end of each month, and so on. But they do not give the maximum depth on the ground at *any one time* during the period of observation. Even if they did, as the weight of snow depends on its density, and the density is not tabulated, the exact weight, as a water-equivalent, is unknown. A fair approximation may, however, be reached in this matter by taking the greatest depth of snow on the ground at the middle or end of any month noted during the period of observation, assuming that that snow was at its greatest possible density and then calculating its weight per square foot. Nevertheless this is not altogether a satisfactory method, and engineers and architects would be benefited if our snowfall records were more complete. I believe that many city building ordinances regarding the weight which a flat and a sloping roof must be able to support might well be revised.

The student of geology and of physiography finds himself at every turn confronted with climatic problems, and can make little progress unless he is familiar with the larger characteristics of climates and with the controls of those climates. If he investigates that most interesting chapter of our earth's history which has to do with the climates of the geological past, he can not evolve any sound hypotheses to account for glacial epochs and interglacial epochs without understanding how our present climates are produced. A climatologist who attempts to read the vast literature dealing with fossil climates—paleo-climatology this branch of our science has come to be named—will inevitably be struck by the fact that many fantastic explanations of past climates would never have been attempted had their authors been familiar with the principles of climatology. Extraordinarily difficult and complex these problems of paleo-climatology surely are. We are still very far from any satisfactory solution of them. Climatologists, as well as geologists, are baffled to-day as they were fifty years ago. But we are all the time making progress, and while the goal is still far distant, we look forward to its being reached. As climatologists we may as well frankly confess that we have no satisfactory explanation to offer of the very puzzling facts which geology has beyond question established in regard to the ice ages and interglacial periods.

The weathering of rocks is immediately controlled, to a large extent, by climatic conditions. In high latitudes, where the ground is snow-covered for part or all of the winter, chemical decomposition must largely cease. Here the actions of frost and of ice—mechanical rather than chemical processes—are highly important agents in promoting rock disintegration. On the other hand, in the rainy portions of the tropics, where, near sea-level, frost and snow and ice are unknown, chemical decomposition, resulting from frequent and heavy warm rains, becomes of paramount importance. Deep decomposition of the rocks is inevitable, and tropical soils therefore have certain typical and well-known characteristics. In deserts, especially deserts at considerable elevation above sea-level, the rocks are

subjected to excessive heating by day and cooling at night. The resulting expansion and contraction crack the rock surfaces; they split, and thus even in excessively arid regions rock disintegration goes on. Blowing sand wears down these rocks and rock fragments, and gradually, as they become smaller and smaller, they themselves become a part of the sands which surround them. Any one who has had the wonderful experience of spending the night under the stars in a high desert among boulders or cliffs has heard the sharp reports like pistol shots which accompany this process of rock disintegration.

To my thinking, the most logical classification of rivers from the point of view of their human relations is one that is based upon climate, and yet, so far as I know, no such classification is in use. There are rivers with a uniform water supply throughout the year, fed by well-distributed rainfall or by rainfall at one season and melting snows at the other. Most rivers have periods of high water and of low water, depending on the seasonal supply. In low-water times they may completely dry up, as is the case, for example, with many of the rivers in California in summer, while during the rainy season or the season of melting snows, deep water or floods will be the rule. Thus many rivers are navigable during part of the year only, and commerce is interrupted during the remaining months. Many rivers flowing into latitudes of severe winters are completely frozen for months each year. Transportation by water then ceases, and travel is often best accomplished by using the frozen surface as a highway. From the mountains surrounding deserts streams flow down onto the arid lower lands and wither away there, in sinks or playas or salt lakes. It is only when the water supply is very abundant, as in the case of the Nile, for example, or of the Tigris and Euphrates, that a river can flow for a long way through an arid region and persist until it reaches the sea. To what extent man can make use of rivers for purposes of travel and transportation, and how far floods may lay waste his cultivated fields or carry away his houses and his bridges, depends, after all, upon the amount of water in the channels.

Erosion by running water is suspended wherever temperatures below freezing last sufficiently long to turn streams into ice.

If the rivers on the windward side of a mountain range are well supplied with water while those on the opposite side are in what is known as the "rain shadow," and are shallow and feeble, the former, other things being equal, will have the best opportunity for work, and will extend their headwaters back so that the water-parting is no longer on the crest of the mountain range but may even be pushed out onto the lowlands on the lee side. Thus, rainfall which originally found its way to the sea on the lee side may eventually be taken as it were across the range to the windward side. This process inevitably shifts the divide in places from the crests of the mountains onto the leeward lowlands. Such a situation has arisen along the southern boundary between Chile and Argentina. Chilean rivers have actually robbed Patagonian rivers of their headwaters, and have in certain instances shifted the water-parting onto the Patagonian plains. In other words, some Chilean rivers start in Patagonia, and what were formerly Patagonian lakes along the eastern base of the Cordillera now drain into the Pacific Ocean. The fact that Argentina rather naturally regarded the crests of the Cordillera as the boundary, while Chile equally naturally considered the water-partings, even when on the Patagonian side, the boundary, really had much to do with the famous boundary dispute between

Chile and Argentina a number of years ago. The difficulty was fortunately adjusted by arbitration. The famous statue, the Christ of the Andes, was erected to commemorate the peaceful ending of what threatened to be a disagreement settled by war. This is a striking illustration of the part played by rainfall, acting through normal physiographic processes, in connection with an international boundary.

There are many other illustrations of geological processes in which climate is concerned. The nature and colors of soils are largely climatically controlled. The action of waves along shore in eroding cliffs, building sand-bars and beaches, and the like, varies with the height and the strength of the waves, and is therefore to a considerable extent dependent on the presence or absence of storms, either near by or at a distance. Storm waves are propagated to great distances from the locality in which the storm is active. Waves run so far ahead of the whirling hurricane winds that produce them that we may often see great rollers coming in on our beaches when the center of the disturbance is far away to the south or southeast. Physiographic forms in large measure correspond to the climate of the region in which they are found, and a skilled physiographer may interpret the climate from the form or, knowing the form, can describe the climate. There are arid-land forms of talus slopes and alluvial fans and of mountains partly buried in their own waste. There are wet-climate deltas and terraces and valley forms. There are the moraines and eskers and other special features of regions once glaciated. A physiographer needs to know his climates if he would fully understand the features of the earth's surface which it is his business to explain. Many valuable deposits of immense economic importance to man owe their preservation to existing climatic conditions. Thus, the famous nitrate beds of northern Chile would dissolve and disappear were that region to become rainy. It is now one of the driest deserts in the world. From it has come vast wealth. The last thing in the world that the people who live in that desolate nitrate desert desire is rainfall. Similarly, the great guano deposits on the Peruvian islands are preserved, with all their valuable chemical properties for soil enrichment, because of the lack of rainfall. Should the great Humboldt Current off the west coast of South America slacken or change its course, should the southerly winds along the Chilean and Peruvian coasts change their direction, the nitrate and guano would cease to exist. A very special and peculiar combination of climatic controls has preserved these two deposits which have been of such immense economic significance to Chile and Peru.

My final illustrations of the part played by climatology in human affairs I shall take from military science. As far back as we have any record of military campaigns and of battles, there is mention of the part played by weather and climate in warfare. Famous cases of this kind were the destruction of the Spanish Armada by a severe storm and the winter retreat of Napoleon's army from Moscow. The evacuation of Boston by the British was hastened by a violent storm which drove some of the British vessels ashore and prevented the debarkation of the soldiers in order to drive away the Revolutionary army from the fortification of Dorchester Heights. Our own Civil War furnished innumerable instances of weather controls over the movements of troops and guns.

It remained for the World War, however, to bring into startling prominence the factor of weather in warfare. There are two aspects of this subject. Military commanders must have knowledge of coming weather as many hours in ad-

vance as possible in order that they may know what conditions to expect in the immediate future. This information is necessary in planning movements of troops, in organizing bombing expeditions, in regulating artillery firing. The World War was the first in which regular weather forecasters were attached to the headquarters staff, and in which scientific weather forecasts were made with the help of an organized body of meteorological observers. Weather forecasting is, however, only one side of the picture, and it is not the one with which we are here directly concerned. The other side concerns a thorough knowledge of the general climatic conditions of the area where the fighting is to be done.

Military commanders should know beforehand whether they will have to deal with heavy snows, with frequent heavy rains, with severe cold, with much low-lying cloud, with fog, with high winds, with dry spells, with dust, with mud, and so on. All this information is readily obtainable in the regular official climatological summaries and in the discussions that usually accompany these tabulated data. It is worse than folly for a military expedition to be taken into a dry region, for example, without making proper provision for a water supply, or into a country of severe winter cold without adequate warm clothing, or into an area of heavy snows without preparation for transport under such conditions. In other words, the high military command should have all possible advance information concerning conditions of temperature, rain or snowfall, winds, clouds, and the like.

The great war furnished many examples of a very complete ignorance on the part of those who should have known about these matters. Each war zone had its own special problems. In the western war zone—the only one in which our own troops were engaged—the outstanding climatic characteristics are the frequent rains at all seasons of the year, the abundance of cloud, the low-lying night fogs, the absence of any extreme cold, the occasional short spells of heat in summer, the irregular varying winds. The climate in that area is a modified continental climate, less severe than that in New England, more like that of the north Pacific coast. Farther east, in Poland and in eastern Prussia, the winters are more severe; there is more snowfall; the cold lasts longer. In fact, Warsaw and Boston have a good deal in common climatically. Much of the fighting in the Italian war zone was carried on under conditions of extraordinary difficulty among the deep snows of the mountains, where avalanches and great cold and almost impossible conditions of transport obtained. The men marched on skis or snowshoes, and used white sheets to make themselves less visible on the snow.

In Mesopotamia the terrific heat and the lack of water caused indescribable suffering among the British troops. Temperatures in the hospital tents were reported as over 130°. Cases of sunstroke and heat prostration were common. The men were so thirsty that, in spite of all orders to the contrary, they drank the polluted water of the Tigris.

But one of the very worst examples of lack of preparedness against climatic handicaps came in the Gallipoli campaign. The Gallipoli Peninsula is in that portion of the Mediterranean climatic zone where dry summers are typical and inevitable. The British troops were landed, and ordered to fight, with an absolutely inadequate supply of water. No proper provision had been made to meet a condition as certain to be found there as night is certain to follow day. After long delays, water was brought from the ships and supplied to the troops, but so inadequate was that supply that the men cut holes through

the hose which carried the water in order to relieve their unendurable thirst, and for a part of the time the daily ration was half a pint of water per man. No wonder that the general commanding the British forces, in his official report, said that much of the lack of success of his campaign resulted from an insufficient water supply. Towards the autumn, when the winter cold set in and snow fell, the suffering among the Anzac troops was again tragic and heartbreaking. Failure to anticipate all these conditions was, perhaps, excusable because of the need of haste in carrying through the Gallipoli campaign, but nevertheless the climatologist sees in this disastrous and unsuccessful undertaking a very sad and a very striking illustration of the need of preparedness on the climatological side in the conduct of a military campaign.

X-RAY APPLICATIONS IN EVERY-DAY LIFE

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I

THE applications of X-rays are becoming so numerous and important in the daily life of every man that it seems of interest to take brief account of some of the achievements and possibilities of this great research agent. To most folks X-rays are a mysterious invisible instrument with which the physician is enabled to see, on a photographic plate or a glowing screen, broken bones or an imbedded bullet or a pin caught in a child's throat, or with which the dentist may examine the roots of an ailing tooth. Some of us may have had our last pair of shoes scientifically fitted by seeing for ourselves the actual positions of the bones of the feet. The pioneer application of X-rays in medical diagnosis is still one of the greatest, but there are many new and equally interesting fields of usefulness. The roentgenologist, after locating an internal tumor or cancer with X-rays, treats it with these rays as a therapeutic agent; the biologist and botanist face the great processes of natural evolution fearlessly and produce by direct irradiation of fruit-flies or tobacco plants an astonishing acceleration of a thousand per cent. in the mutation of species and thus profoundly affect the characteristics of future generations; the physicist has been using X-rays as magic eyes with which to explore the interior architecture of atoms, and finds there marvelous infinitesimal planetary systems ordered by the laws of a rational universe from the simplest hydrogen atom to the most complex uranium atom; the chemist is discovering new chemical elements by measuring the X-rays characteristically emitted by materials when bombarded by electrons; to the chemist also is being revealed the fine structure of the unit building blocks of all matter; and now industry is finding X-rays of immeasurable assistance in the solution of some of the most difficult problems of producing commodities of certain and satisfactory quality. For X-rays yield the knowledge of the ultimate construction of matter which determines even the most practical and useful properties.

We may now ask, what are these remarkably versatile X-rays? In every respect are they identical with ordinary light except that the wave-lengths are only 1/10,000 as great, on the average, as visible light. They are electromagnetic vibrations propagated as waves or as tiny bundles of radiant energy through space without transference of matter. X-rays, the cosmic rays which come from the far reaches of the universe and are able to penetrate eighteen feet of lead, the gamma rays from radium, the ultra-violet, infra-red, and radio waves are all like light except in wave-length.

In all this great range of rays, from those only 1/100,000,000 cm long to those hundreds of meters long used in radio broadcasting, the human eye is sensitive only to that extremely narrow band we call light. Because X-rays are shorter than light it follows that they are more penetrating, that they should pass through materials opaque to light, and that they should be associated with a finer subdivision of matter than is apparent by examination in visible radiation. As a matter of fact, we find that X-ray wave-lengths are of the same

order of magnitude as the sizes of the ultimate atoms of all material things. By means of X-rays as the messenger, therefore, the knowledge of the true unit building blocks of matter and their interrelationships is gained.

While X-rays penetrate matter opaque to light, they are absorbed differentially because any inhomogeneity or defect in an object has a different density and absorbing power than the main body of the material. Hence X-rays which pass through such an object will have varying intensity, and when they strike a photographic plate a shadowgraph of the specimen is registered which may also be visually observed on a fluorescent screen. Observation of bones through the less dense tissues is of course the most familiar example of this science of radiography. Think what medical and surgical diagnosis would be to-day without X-rays, not only for absolute information on bone fractures and diseases but also for tuberculosis, tumors, gallstones, blocking in the spinal column and almost all the long list of pathological conditions of the body!

A great experience is accumulating to prove that even malignant internal cancers, too often unsuspected until far advanced, may be successfully cured or at least greatly alleviated by X-ray and radium treatments if diagnosed in the early stages. Radiographs of the skull are so individualistic that they will soon supplement finger prints as a method of identification of persons. In the University of Illinois recently a curious and obscure disease of carp in the Illinois River which curtails normal growth has been diagnosed as a type of rickets from X-ray photographs where dissection methods largely failed. In a great exhibit of medical X-ray photographs such as that at the recent meeting of the Radiological Society, one is deeply moved by the enormous number of ills to which these bodies of ours are subject, and consequently by the advisability of regular X-ray examinations even in good health.

There are also many inanimate things whose ills may be diagnosed just as successfully. One of the most important is the examination of metal castings for presence of internal gas cavities, sand and slag inclusions, pipe cavities, porosity, cracks and metal segregation. The result is perfectly sound castings where the safety of human life is demanded, as in high-pressure power plants, oil stills and aircraft motors. The greatest X-ray laboratory devoted to this subject is located at the Watertown Arsenal in Massachusetts. Some of the other radiographic applications in this country are: the examination of welds for soundness; of coal for slate and ash; of minerals for classification; of golf-balls for symmetry of the center; of cord tires for adhesion of rubber; of reclaimed rubber for nails and foreign matter; of shells and grenades for proper filling of explosive; of wood, particularly when used in airplanes, for wormholes, cracks and knots; of trees and telephone poles for interior soundness; of logs in veneer manufacturing plants for imbedded nails liable to ruin cutting blades; of walls for hidden pipes and wires; of mystery packages, some of which may be sent as undesirable gifts by anarchists; of false-bottom baggage evading customs officials; of metal pipes and capillaries for measurement of internal diameters; of clogged gasoline lines; of radio tubes for proper position of electrodes; of glass and pigments, and of Swiss cheese for the location and size of the highly prized holes. The Fogg Art Museum at Harvard University and the Metropolitan Museum in New York are X-raying old pictures and discovering retouching and sometimes infinitely more valuable masterpieces entirely painted over. And so, many other interesting shadowgraph applications might be enumerated.

Whenever there is a need to examine the interior of any object, X-rays provide in a sense a powerful extension to the limits of our vision. Now even the science of Egyptology lays a claim to this tool, for most of our knowledge of ancient anatomy is derived from radiographs of mummies!

II

In beginning our survey of the applications of X-rays in every-day life, we found that these rays are like ordinary light in every respect except that the wave-lengths are much shorter. On this account, X-rays will penetrate matter which is opaque to visible light and register shadowgraphs of bones, teeth, defective steel castings, welds, golf-balls and many other objects, the denser portions of the interior standing out in relief against the portions which do not absorb X-rays so readily. This constitutes the great X-ray science of diagnosis, whether it be medical or the examination of a vast number of inanimate objects for internal gross structure or defects. But in disclosure of gross structure X-rays have far from exhausted their possibilities. If we but use them properly, they will lead directly to a knowledge of the *ultimate* structure of matter, clear down to the atoms and molecules which constitute the very minute unit building blocks of the material universe. Practically every property, useful and otherwise, of the things we know and use every day, depends fundamentally upon the size and shape and number and arrangement in space of these unit building blocks, which are far too small to be seen by a microscope. If these are known from our X-ray examination of materials, then it follows that we shall discover with absolute finality the primitive cause of a satisfactory or unsatisfactory behavior of an object which we can see and use. Suppose we take a strip of iron and slightly etch it with acid. The crystal grains are now easily seen with the eye, each appearing perfectly homogeneous. Under the microscope, however, a homogeneous grain may show a heterogeneous fine structure. One of these microscopic units with X-rays indicates that it in turn is built up of ultimate crystal units. What is this unbelievably small unit crystal of iron—this block which is combined with an enormous number of others just like it to give the crystal grain which the human eye may see? We know it to be a tiny cube with an atom of iron at each corner and one in the center; the cube measures less than 3/100,000,000 cm on a side; it is the last thing that is still solid crystalline iron—its properties are those of the visible crystal grain of iron—it is the ultimate iron. Other metals, such as tungsten and chromium, have the same type of ultimate cubic architecture, but these units have different sizes than that which characterizes iron. Still other metals, such as the ductile aluminum, silver and gold, have a different type of crystal unit. The fact that this unit crystal is built in so orderly and perfect a fashion explains why X-rays yield such remarkably fundamental information. Most of us are acquainted with the fact that if we rule parallel lines very close together on glass or metal, we have a grating which will diffract ordinary white light and like a prism spread the beam out into a rainbow or spectrum. Now if X-rays are like light they should be similarly diffracted by a grating, but it has never been possible to rule these lines sufficiently close so that the X-rays with their far shorter wave-lengths are affected except under very special conditions. Thus, from the date of discovery of X-rays by Röntgen in 1895, till 1913, there were no gratings known for the analysis and measurement of beams of X-rays, although it was recognized that an average wave-length of X-rays was

1/100,000,000 cm, and that a grating must have parallel spacings of the same order of magnitude—that is, about the size calculated for the ultimate atoms themselves. It was von Laue, a German, who finally reasoned that nature has literally deluged us with perfect X-ray gratings—namely, crystals of every conceivable kind. For in a crystal the atoms or molecules are marshaled perfectly row on row like West Point cadets except that the crystal is three-dimensional and has equidistant planes of atoms, spaced a few hundred millionths of a centimeter apart, which diffract X-rays. Von Laue ordered the experiment performed of passing a beam of X-rays through pinholes in lead blocks, and then through a crystal of zinc sulfide with a photographic plate behind the crystal to register the result. The plate showed an array of sharp spots forming a figure of perfect symmetry—an eloquent verification of the prediction that crystals are built up from their very beginnings in perfect order not only for those specimens with beautiful faces like a diamond, but also for materials which outwardly seem to manifest no such regularity. And now even liquids, which we have always classed as distinctly amorphous because molecules are free to move about, manifest remarkable attempts at organized structure, for they produce definite though simple X-ray diffraction patterns. Thus do we arrive at a great branch of X-ray science whose achievements have already formed one of the most brilliant pages in science, and yet whose possibilities are well-nigh limitless. For with some known crystal as a grating we can measure the whole unknown range of X-ray wave-lengths or, *vice versa*, with X-rays of known wavelength we can analyze the unknown ultimate structure and unit dimensions of new crystals, and now even of powders, jellies and liquids.

Before proceeding to the practical application of this fundamental method of research to the problems of structure, properties, manufacture and use of chemicals, metals, alloys, textiles including rayon and silk, rubber, ceramics, paints, lubricants, waxes, cement and numerous other materials, a brief description will be given of the new X-ray laboratory in the chemistry department of the University of Illinois which is primarily devoted to these fine structure studies. The essential parts of an X-ray apparatus are the X-ray tube, a source of high potential, methods of defining the X-ray beams through small pinholes and slits, water-cooling systems for keeping the tubes cool during continuous operation, various protective devices for the experimenter against X-rays and high voltages, and photographic equipment. An X-ray tube of the Coolidge type is an evacuated bulb in which there are two electrodes, a tiny spiral of tungsten wire which is heated to incandescence by an electric current, and a smooth-faced metal target opposite. The hot wire emits electrons as discovered by Edison. When a voltage of 30,000 to 80,000 volts is applied, these electrons are driven like miniature cannon balls across the gap and bombard the target. They are stopped and their energy converted to X-radiation which passes out through the tube walls. The laboratory has three complete apparatus units with which it is possible to obtain X-ray photographs of twenty or more specimens simultaneously. The exposures range from a few minutes to as many as one hundred hours, depending upon the material. Another tube which depends upon residual gas instead of a filament for operation produces so powerful a beam of X-rays that results are obtained in only about one tenth the time usually required. An ingenious spectrograph makes it possible to use several diffraction methods, depending

upon the material and the type of information desired.[1] Still another X-ray unit in the chemistry department is being devoted solely to further study of the new element illinium, discovered by Professor B. S. Hopkins and associates. Some of the interesting problems under investigation on the structure and properties of materials will be considered in the next section.

III

We have now found that X-rays lead us from information concerning the interior gross structures of material to knowledge of ultimate fine structures far beyond the power of any microscope. Nature has built all solid crystalline matter according to so orderly a plan that all the atoms and molecules lie on parallel planes which are spaced at distances which compare with the short wave-lengths of X-rays. Thus crystals, each one in its own definite characteristic fashion, diffract X-rays just as finely ruled lines on glass diffract ordinary light. We are able to deduce the structure and size of the unit crystal cell serving as the architectural pattern which upon multiplication in all directions builds up the visible crystals. We determine the size, shape and constitution of the single brick in an apparently homogeneous structure hundreds of millions of times larger. If this brick is slightly deformed by stress the X-ray patterns indicate it. If the material is a single crystal grain with all the tiny ultimate units perfectly aligned, or if it is a powder or aggregate of small grains chaotically heaped together, or if it is an aggregate with the grains oriented in a common direction as in asbestos or cotton fibers, or metal wires or rolled sheet, the X-ray patterns are perfectly characteristic. There are some twenty different types of fundamental information which may be ascertained from diffraction data, and these account in the realest sense for the actual behavior of materials.

So rapid has been the growth of this chemical science of X-rays that more than 500 kinds of crystals have been singularly analyzed, ranging in complexity from common salt or aluminum to very complex silicate minerals[2] and organic compounds. Prior to X-ray analysis the chemist's knowledge of the solid state was decidedly limited and he strove to avoid this by melting or dissolving the substance before he attempted to do anything. Now he is trying to crystallize everything and determine the structure as our knowledge advances of the amazingly orderly forces which hold atoms and molecules in marshaled array in space. We are now thoroughly familiar with the crystalline architecture of almost all the useful metals and alloys. We understand that the ductility and malleability of aluminum, copper, gold, silver, and the brittleness and hardness of chromium, tungsten or molybdenum are properties directly related to the plan of building in the unit crystal. We can picture exactly from the X-ray data how zinc atoms elbow their way into the little unit cubes of copper and literally push the sides of the tiny structure apart to form brass. We now recognize four kinds of solid iron: α, β, γ, δ, depending upon the temperature and differing in magnetic properties, but X-rays tell us that α, β and δ iron have exactly the same crystalline structure, and that magnetism is therefore not a property residing in crystalline structure. So, the whole problem of the constitutions and range of stability of metals and alloys is coming to be known and properties definitely predicted. And now, in addition,

[1] A complete description of the laboratory illustrated with photographs of apparatus and typical diffraction patterns is presented in a paper in *Industrial and Engineering Chemistry*, 20, December, 1928.

[2] The compound $H_4[SiO_4W_{12}O_{30}(OH)_{18}]$ has been analyzed recently in the writer's laboratory.

the processes and results of fabrication and heat treatment lead us to a new industrial science. When a metal is drawn into a wire or rolled into a sheet remarkable changes occur in X-ray patterns. The mechanism of working may be quantitatively deduced—for example, that in an aluminum wire every tiny ultimate cube is turned so that the cube diagonals are all parallel to the wire axis, or that in a copper sheet all the little cubes with one atom of copper at each corner and one in the center of each face lie with a cube face in the plane of rolling. All such worked metals are obviously characterized by strongly directional properties, and it is the task of heat treatment to remove this condition, particularly if the metal is to be formed into useful articles. There is no more remarkable achievement of X-rays than the commercial control of annealing which will assure a uniform product of highest quality upon the basis of absolute knowledge of recrystallization processes. With such a control a technique of manufacture inevitably results which involves no greater expense or difficulty.

Again and again X-ray researches have this background of higher standards, better quality, knowledge of the ultimate and the diagnosis and alleviation of ills of every kind. It is little wonder, then, that there is kindled in the worker a burning enthusiasm which drives him on to explore new fields of application for this great science.

It is a common belief that heat-treating metals for a long time at low temperatures in order to remove strains and directional properties achieves the same results as annealing for a short time at high temperatures. New X-ray studies show that this precept is far from true, particularly for silver and copper. In the presence of five hundredths of one per cent. of iron the recrystallization temperature of silver is brought down to room temperatures, and all silverware under these circumstances would soon be ruined. As a matter of fact this amount of iron *is always present* except in very specially refined silver, but its deleterious effects are always offset by the presence of the same slight amount of copper. This curious metallurgical fact as ancient as silver itself has come to light after hundreds of years through the agency of X-ray analysis.

Cast steel is characterized by an X-ray pattern which clearly shows a condition of great internal strain, even though it may be free of gross imperfections. The purpose of heat treatment is to relieve this condition, but until now there has been no control method sensitive enough to discover the *best* annealing technique so that the ideal structure may be obtained. From X-ray data alone it was possible in this laboratory recently to plot regions of equal strain in a large casting, and thus to predict where it would fail or how it should be annealed properly. As a result several large manufacturing plants have based their annealing methods on this scientific research basis instead of empiricism. Similarly, we might describe X-ray studies of the cause and prevention of transverse fissures in steel rails, which have caused so many wrecks, the proper manufacture of electric steel with lowest magnetic loss, the proof of the great superiority in terms of ultimate structure of welds made in a hydrogen atmosphere as compared with the ordinary arc method, the desired structure for aluminum alloys, the changes during metal fatigue, and many other problems. Every metal product which finds usefulness in our daily life is a potential subject for X-ray fine structure research—and then only a single possible field has been touched.

Space permits only a brief enumeration of a few representative X-ray studies on non-metallic materials now

being made in the laboratory at the University of Illinois and elsewhere.

Asbestos: A clear differentiation between numerous varieties appearing outwardly the same but differing widely in practical behavior, and a method of identifying the mines from which various specimens of the same type come;

Lime: Discovery of the cause of plasticity and methods to render non-plastic lime useful;

Enamels and pigments: Composition, particle size and crystallization as functions of covering power, tint, wear, etc.;

Lubrication: A definite knowledge of mechanism in the lining-up of long grease molecules in successive layers like a stack of carpets with the pile of each carpet representing the molecules which slide over each other instead of one metal surface on another;

Waxes, soaps, alcohols and other organic compounds: The analysis of crystalline structure, actual measurement of the sizes of molecules, the testing and verification of the structural theories of organic chemistry (as for example, absolutely definite proof of the benzene ring);

Ceramic materials: Construction, transformations and internal strains, as in spark plugs;

Rubber: The discovery that this remarkable substance develops a crystal-like fiber pattern upon stretching (as does also a muscle fiber), analysis of which removes much of the conjecture from our scanty knowledge; the development of a method of stretching rubber 10,000 per cent. to threads insoluble in the solvents which usually dissolve rubber easily; and the establishment of these unique criteria never yet found in artificial or synthetic rubber;

Textiles: The behavior and constitution of the crystalline threads of cellulose and silk, and the deduction of a vastly improved type of rayon;

Catalysts: The deduction of optimum constitution and particle size for high pressure synthesis of methanol and other products.

Gelatine, biological structures, road materials, paints, nitrocellulose explosives, lacquers and transparent wrappers, paraffin, the cause and prevention of cracking of patent leather, liquids of all kinds, carbon, cement, adhesives, paper, the tiny objectionable stones in pears, electroplating, food products—all of these and many more materials are yielding their secrets of constitution and of their good or bad practical behaviors in everyday use to the searchings of X-rays. Though these rays move in mysterious ways their wonders to perform, they are serving mankind every day in the cause of better materials, better health, better knowledge of the universe ordered by a supreme intelligence.

EQUIPMENT FOR MEASURING LIGHTNING VOLTAGES

By EDWARD BECK

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

BECAUSE of the great expansion of electric power systems during the past ten years, the disturbances caused by thunder-storms have assumed such importance that much effort is being expended on studies of their characteristics. The disturbances which are generated in the wires of a transmission line are exceedingly high voltages which may change at the rate of hundreds of thousands of volts in a millionth of a second. These voltages are known as transients. A knowledge of their exact characteristics is of great importance. In order to obtain it, it is necessary to record the transient in its entirety. As the transient may pass in a few millionths of a second and since the time of its occurrence can not be foretold, the making of such a record appears to be extremely difficult. As a matter of fact, it has been impossible until recently except in the laboratory under controlled conditions. Studies on actual transmission lines during their normal operation have been made possible by the cathode ray oscillograph developed by Dr. Harold Norinder, a Swedish scientist and a consulting engineer for the Westinghouse Electric and Manufacturing Company, who has the distinction of being the first to make records of lightning transients on transmission lines.

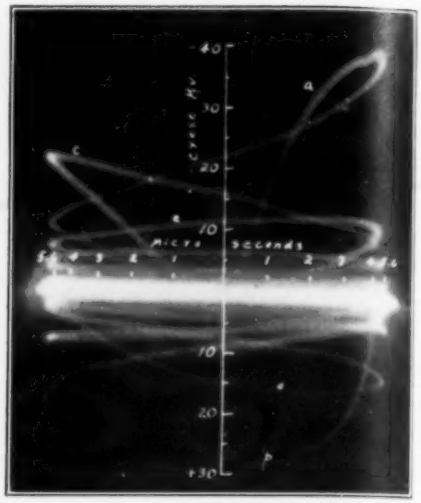
The Norinder cathode ray oscillograph makes a record on a photographic film of the entire transient disturbance from its very beginning to its end. As we are dealing with periods of time measured in millionths of a second, the action of the oscillograph must be extremely rapid. The ordinary instruments with mechanical moving parts are too slow in responding because of the inertia of their moving parts. The cathode ray oscillograph has for its moving element a beam of electrons whose inertia is practically zero. This electron beam impinges on a photographic film which it affects in the same manner as light. The electron stream, or cathode ray as it is commonly called, is deflected by a system of electrostatic plates coupled to the transmission line. Abnormal voltages occurring on the transmission line are instantaneously communicated to these plates which im-

HIGH VOLTAGE SOURCE FOR GENERATION OF CATHODE BEAM

REAR VIEW, SHOWING TRANSFORMERS, CONDENSERS AND RECTIFIER TUBES.

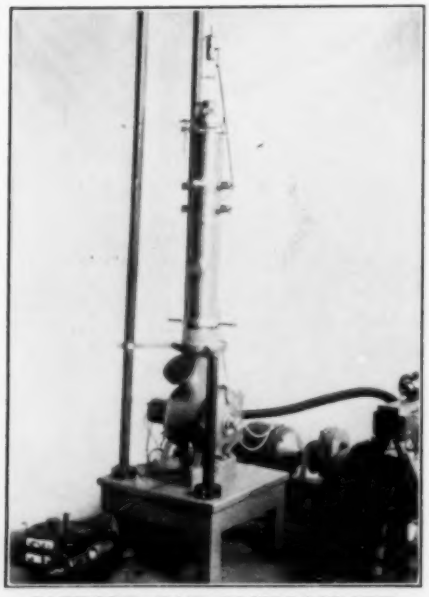
mediately exert a force on the cathode beam. Since it has no inertia, it immediately is deflected, thereby drawing a line on the photographic film, thus making a permanent record of the lightning disturbance.

The complete cathode ray oscillograph is about seven feet long and weighs approximately two hundred pounds. It may appear strange that an instrument of these proportions will make such delicate measurements; nevertheless it is a fact that it will respond with the greatest degree of sensitivity to the most rapidly changing phenomena. In order to operate the instrument, it is necessary to produce inside of it this beam of electrons. This is done by applying a high unidirectional voltage between a cathode located at the extreme top of the instrument and an anode slightly below the cathode. The electron stream generated at the cathode passes through a small hole in the anode and continues to the photographic film at the bottom of the oscillograph. On its way to the film, the beam passes between a system of electrostatic plates whose fields of force are determined by the lightning disturbance. A cathode beam may be produced only in an extremely low gas pressure. It is therefore necessary to exhaust the inside of the oscillograph to a pressure which is only about 1/200,000th of the outside air. To procure this low pressure and to maintain it in the oscillograph requires a highly efficient system of vacuum pumps. The pumping system is one of the most important accessories to the oscillograph. Without a reliable one, the instrument may fail to work at critical moments. Generally, two stages of pumps are used, the first a so-called rough pump which will produce a fairly low pressure when exhausting into the open air. The second stage is a Holweck high vacuum pump which exhausts into the low pressure created by the first pump.



RECORD OF A TRANSIENT ON A TRANSMISSION LINE

MADE BY MEANS OF A CATHODE RAY OSCILLOGRAPH. NOTE THAT ONE SWING ACROSS THE FILM REPRESENTS A TIME INTERVAL OF ONLY 11.2 MILLIONTHS OF A SECOND.



CATHODE RAY OSCILLOGRAPH

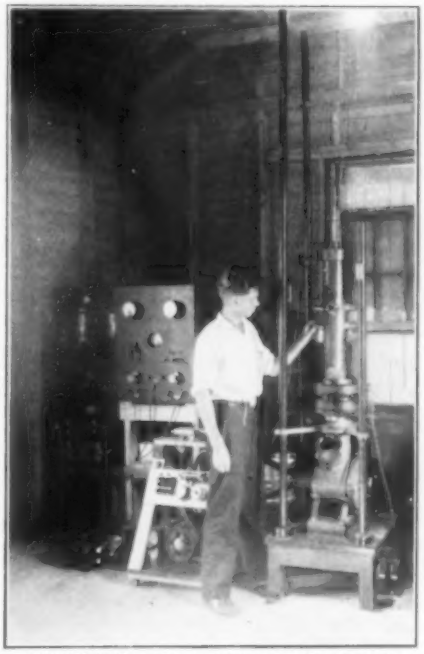
USED TO SECURE LIGHTNING RECORDS. THIS IS THE FIRST INSTRUMENT DEVELOPED TO GIVE COMPLETE AUTOMATIC RECORDS OF TRANSIENTS ON ELECTRIC SYSTEMS.

With the oscillograph and the proper pumping system, there is still required a source of high unidirectional voltage to generate the cathode stream. This voltage must be of the order of 30,000 to 60,000 volts, and must be uniform. It is obtained by means of transformers and high voltage rectifier tubes. The current drawn from this source is of the order of a fraction of a milliampere.

In order to obtain a clear record of these transients, showing the time durations which are involved, it is necessary to have a timing axis appear on the film. For relatively slow phenomena, this axis may be secured by rotating the film on a cylindrical drum. The drum used has a peripheral speed of about 12,000 feet per minute. For the very rapid transients, much higher speeds are necessary. These can not be obtained by mechanical means. For this purpose, the film is left stationary, and the electron beam is caused to travel back and forth across the film at a predetermined rate, usually by means of a high frequency oscillator which impresses a deflecting voltage on the beam at right angles to the system producing the voltage deflection. The oscillator used for this purpose is very similar to the oscillators used in radio practice. Its frequency is readily adjustable between wide limits, and by its use the current scale may be accurately set.

OSCILLATOR FOR TIMING AXIS

REAR VIEW.



INTERIOR OF A FIELD STATION

The equipment as described above is being used by the Westinghouse Company in some field tests by which much valuable data on lightning disturbances are being secured. Two installations have been made in the Tennessee Mountains on a 154,000 volt transmission line of the Aluminum Company of America. Besides the cathode ray oscillograph, which is the most important device used in these investigations, there are employed also other instruments to shed further light on the mysterious ways of lightning. Among these instruments are klydonographs, osisos, cameras and alarm circuits.

The klydonograph is an instrument which will record the maximum transient voltage occurring on a transmission line without, however, exposing any details as to its shape or duration. Until the advent of the cathode ray oscillograph, the klydonograph was the

most important instrument for investigation of lightning disturbances on transmission lines. Now it supplements the data obtained by the oscillograph by measuring the surge voltages occurring at different points along the transmission lines being investigated.

The osiso is a small oscillograph used for the recording of voltages or currents. In the lightning test it is used to locate the position of the lightning stroke. It is accomplished by measuring the time interval between the lightning stroke and the arrival of the thunder noise at the observation station. Microphones translate the noise of the thunder into electric currents which are recorded on the osiso. The time which elapses between the lightning stroke and the thunder is shown by the interval between the recording of the electrical disturbance and the recording of the thunder noise.

Further information about the lightning stroke is secured by means of a special camera which will photograph the entire horizon at once. A lightning stroke occurring anywhere above the horizon will record its appearance on a photographic plate. In conjunction with the data obtained with the cathode ray oscillograph, it is hoped that some relation will be found between the various characteristic lightning strokes, their location relative to the transmission lines, and the disturbances which they cause on these lines.

Radio receiving sets and a special form of transient relay which rings a bell are employed to announce the approach of a storm. When such an alarm is received, all the apparatus is put into operation and the oscillograph tested so that it may be ready when the storm arrives.

There are many details in connection with the field laboratories which are of interest, such as the special measures which are involved in the construction of the laboratories, the obtaining of adequate supplies of power and water, and communication between stations. The objects of most interest, however, are the newly developed pieces of equipment such as have been described in the foregoing paragraphs.

With this equipment now available, the intensive studies being made of lightning phenomena will within the next few years clear up many of the unknown factors involved in lightning disturbances.

ONE OF THE FIELD LABORATORIES EMPLOYING OSCILLOGRAPH EQUIPMENT

THE PROGRESS OF SCIENCE

THE CONVOCATION WEEK MEETING IN NEW YORK

THE meetings of the American Association for the Advancement of Science and of sixty-four associated scientific societies held during the week following Christmas fulfilled all the predictions made by the president, Dr. Henry Fairfield Osborn, in the article printed in the last number of this magazine. It indeed surpassed them, for by common consent there has not hitherto been held in this country and perhaps not elsewhere a meeting at which so many contributions were presented by so many scientific men, or at which the arrangements for their scientific programs and their entertainment were so complete.

The approximate figures are 2,200 papers and addresses presented by 1,900 different individuals at 250 sessions. The registration was about 4,000; the total attendance perhaps 50 per cent. larger. The printed program extended to 350 pages; an examination of the titles indicates how completely the whole field of modern science was covered by the research papers and by the addresses and sessions of general interest.

A special feature of the meeting was the series of lectures arranged by President Osborn at the American Museum of Natural History, followed every evening by a reception with the opening of the whole museum on the first evening and of the halls appropriate to the lectures on subsequent evenings. The lectures in the evening and in the late afternoon were by the most distinguished American men of science—the retiring president of the association, Professor A. A. Noyes, on chemistry; Professor Charles P. Berkey, on Asiatic exploration; Professor Arthur H. Compton, on physics; Professor William Morton Wheeler, on biology; Professor Harlow Shapley, on astronomy; Professor Franz Boas, on anthropology; Professor Bailey Willis, on geology, and others. Two of these addresses are printed in the present issue of the MONTHLY, which hopes to have the privilege of printing others. There were also lectures by Professor G. H. Hardy, of Oxford, and by Professor H. H. Turner, of the same university, the latter having been sent as a special representative from the British Association.

Columbia University and Teachers College entertained a large proportion of the section meetings and the special societies, each of which had its own program, including many sessions planned to be of general interest to all scientific men and indeed to the wider public which is coming to realize the dominant place of science in modern civilization. The only difficulty was the conflicts. If all the papers had been given in succession at the rate of seven a day the meeting would have lasted for a year. At Columbia University was the scientific exhibit which provided a continuous *conversazione* through the week.

In addition to Columbia University and the American Museum of Natural History some forty other scientific and educational institutions of the city acted as hosts, placing their facilities at the disposal of visiting scientific men for meetings or for visits. Especially to be mentioned are the reception at the Metropolitan Museum of Art and the Philharmonic Symphony Concert in Carnegie Hall. At the latter President Osborn, in thanking the conductor, Mr. Mengelberg, said that perhaps never before had so many scientific men been assembled in one audience.

It was the fifth meeting of the American Association for the Advancement of Science in New York and the third of

DR. ROBERT A. MILLIKAN

the convocation week meetings held after Christmas in cooperation with the associated scientific societies. During the more than fifty years of its history in the course of the last century the association met only once in New York, when in 1887 Dr. S. P. Langley, secretary of the Smithsonian Institution, was president. In 1900 the meeting, still in summer, was under the presidency of R. S. Woodward, then professor in Columbia University and later president of the Carnegie Institution. There were then only 1,200 members of the association; the increase to the present 17,500 was in large measure due to the action taken at that meeting in establishing *Science* as the official journal of the association. The convocation week meeting of 1906 was held in December under the presidency of Dr. William H. Welch, long dean of the medical school of the Johns Hopkins University, leader in the development of scientific medicine. Ten years later Dr. Charles R. Van Hise, the distinguished geologist, president of the University of Wisconsin, presided. At about that time it was arranged that meetings should be held once in twelve years in New York and in the intervening four-year periods in Washington or in Chicago. These are the larger convocation week meetings in which the executive officers are elected for the ensuing four-year period.

At the recent meeting Professor Burton E. Livingston, professor of physiological botany at the Johns Hopkins University, whose conduct of the association during the past eight years has met the unanimous approval of American men of science, was reelected permanent secretary. Dr. Frank R. Lillie, professor of embryology at the University of Chicago, was elected general secretary, and secretaries were elected for the fifteen sections. Distinguished scientific men to serve for one year were elected as chairmen of the sections and vice-presidents of the association.

Full accounts of the meeting, prepared by the permanent secretary of the association with the cooperation of the secretaries of the sections and of the associated societies, will be published in the issues of *Science* for January 25 and February 1. Copies may be obtained without charge by members of the association who do not receive the journal regularly, and by others who remit the cost, by addressing the office of the permanent secretary of the association in the Smithsonian Institution Building, Washington.

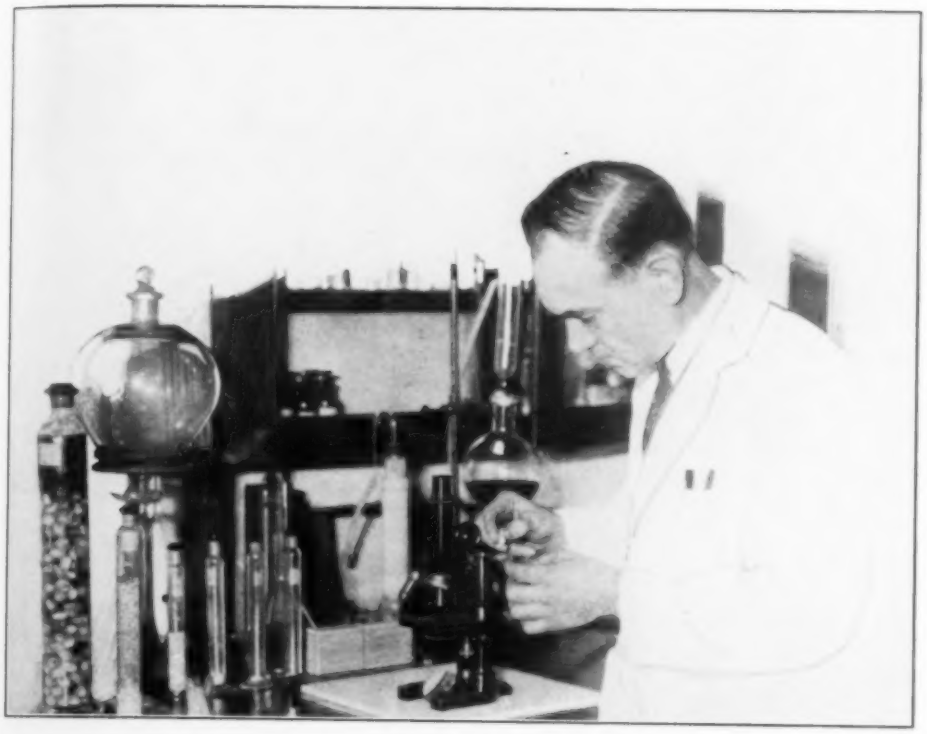
THE PRESIDENT OF THE AMERICAN ASSOCIATION

THE distinguished line of succession in the presidency of the American Association was continued by the election of Dr. Robert A. Millikan to follow Dr. Henry Fairfield Osborn. It was an open secret among scientific men that when it came the turn to elect a physicist it would be Dr. Millikan. The nominating mail ballot from all members of the association was nearly unanimous except in the case of those who did not understand that there is a policy of alternation between the physical and natural sciences or who cast a complimentary ballot for a biologist.

Dr. Millikan is one of the few American men of science who has continued to carry forward research of the highest order while at the same time constantly engaged in public service for science. For example, he came from the Pacific coast to attend the meeting of the National Academy at the end of November and again in December to attend the meeting of the American Association. He is foreign secretary of the National Academy, vice-chairman of the National Research Council and the American member of the committee on intellectual cooperation of the League of

RECIPIENTS OF NOBEL PRIZES

PHOTOGRAPH TAKEN AT STOCKHOLM AT THE TIME OF THE CONFERRING OF THE NOBEL PRIZES. ON THE LEFT IS DR. ADOLPH WINDHAUS, PROFESSOR IN THE UNIVERSITY OF GÖTTINGEN, AND, ON THE RIGHT, DR. HEINRICH WIELAND, PROFESSOR IN THE UNIVERSITY OF MUNICH. THE AWARDS FOR 1927 AND 1928 WERE MADE TO BOTH FOR THEIR DISTINGUISHED WORK IN PHYSIOLOGICAL CHEMISTRY. IN THE CENTER IS MME. SIGRID UNDSET, THE NORWEGIAN, WHO RECEIVED THE PRIZE IN LITERATURE.



DR. OLIVER KAMM

RESEARCH DIRECTOR OF MESSRS. PARKE, DAVIS AND COMPANY, THE RECIPIENT OF THE THOUSAND DOLLAR PRIZE OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. THE AWARD WAS MADE TO DR. KAMM FOR HIS PAPER, ENTITLED, "HORMONES FROM THE PITUITARY GLAND," WHICH HE PRESENTED BEFORE THE SECTION OF CHEMISTRY OF THE ASSOCIATION.

Nations. His great executive work has been in establishing with Dr. George Ellery Hale the California Institute of Technology as one of the world's chief centers of scientific research. The institute has provided two of the three last presidents of the American Association and it may provide the next two. The California Institute has no president, Dr. Millikan being chairman of the executive council as well as director of the Norman Bridge laboratory of physics.

Dr. Millikan is the author of an even dozen books, alone or in cooperation with his colleagues in physics, covering a wide field from the electron to the relation between science and religion. The best known of his researches, the earlier of which won him the rare honor of a Nobel prize, are probably the following:

(1) The isolation and measurement of the electrons, which work furnished the most direct and complete demonstration yet found of the atomic structure of electricity, and makes it possible to count the number of molecules in any weight of any simple substance with as much certainty as can be attained in counting the inhabitants of a city.

(2) The direct photoelectric determi-

MEMORIAL TO LOUIS PASTEUR

nation of the fundamental radiation constant known as Planck's h, which constituted the first direct experimental establishment of the validity of an equation which Einstein had suggested in 1905, and which has now become scarcely second in importance in the electromagnetic theory of the equations of Maxwell.

(3) The study of Brownian movements in gases constituted one of the strongest links in the chain of evidence which finally silenced all opposition to the atomic and kinetic theory of matter —an opposition actively led by Ostwald and formally renounced by him about 1915, with specific reference to the studies of Dr. Millikan and his pupils.

(4) The work on the extension of the ultra-violet spectrum reported in a series of papers from 1920 to 1923 pushed the limits of explored frequencies in the ultra-violet two octavos farther down. This study completed the work begun by Moseley in establishing the order of progression or of evolution of the elements by means of the only completely reliable agency now available for determining that order, namely, the character of the radiation emitted by the constituent electrons within the atom.

(5) The discovery reported in 1923 of "The law of motion of a particle falling toward the earth after it enters the earth's atmosphere" settles definitely one of the historic problems of the kinetic theory which has been the subject of controversy among physicists for seventy-five years.

(6) The experimental study, with Dr. I. S. Bowen, of the spectroscopic properties of light atoms in all stages of "stripping," *i.e.*, when either completely stripped, or partially stripped, of their valence electrons. The spectroscopic laws discovered through this study was one of two equally potent causes leading to the introduction by Uhlenbeck and Goudsmit in 1925 of the new and fundamental conception of "the spinning electron."

(7) The discovery of the laws governing the extraction of electrons from metals by fields alone furnished the first direct experimental proof that the electrons in metals do not share appreciably at ordinary temperatures in the motions of thermal agitation, but do begin to share at sufficiently high temperatures. It begins to clear up the mysteries surrounding the nature of metallic conduction.

(8) The study of the nature and properties of cosmic rays brought to light in 1924 the best evidence yet found for the existence of a very high frequency radiation of cosmic origin, which appears to shoot through space uniformly in all directions.

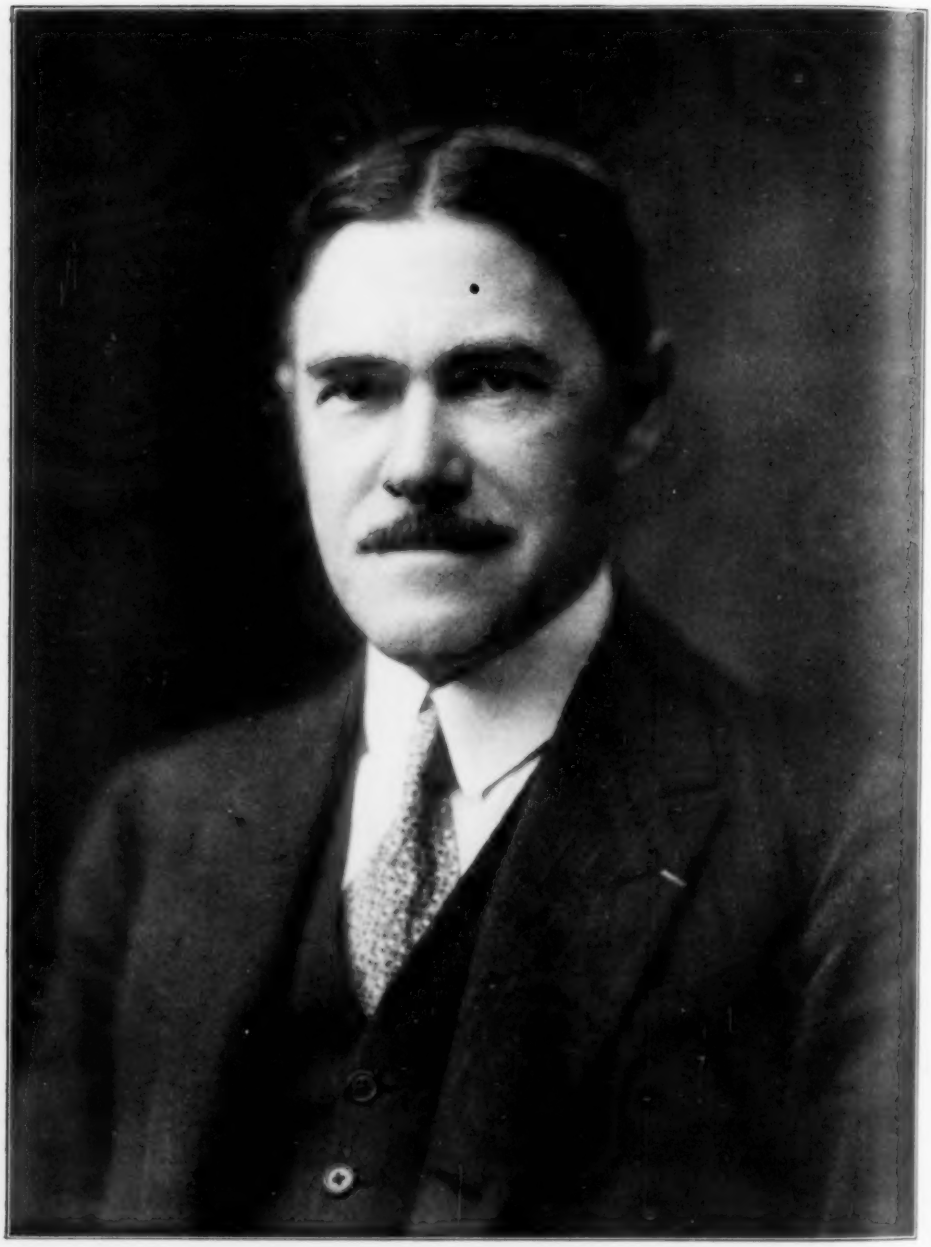
MEMORIAL TO LOUIS PASTEUR IN CHICAGO

A MEMORIAL to Louis Pasteur was dedicated Saturday, October 27, 1928, in Grant Park, Chicago. The memorial is a monument twenty-eight feet high, and consists of an ornamental shaft upon which is placed a bust of the great scientist which is an excellent likeness of the man. The base is twenty-two by twenty-six feet, and both base and monument are in Carrara marble.

The memorial is located at the west end of the Field Museum of Natural History, and therefore bears an appropriate relation to the great museum and the accomplishments of a great naturalist.

The monument was designed and executed by Leon Hermant, the celebrated sculptor, and Mr. Edward H. Bennett had charge of the architectural features including the landscaping and constructing the foundation.

The memorial was built with funds obtained by popular subscription from



Bashford Dean
1925.

To Prof. J. McKeen Cattell, with great esteem and appreciation

approximately one thousand contributors, including members of the medical profession, members of Chicago French societies and other organizations as well as many individuals.

On the back of the shaft is a bronze plate which carries this inscription:

Louis Pasteur
1822–1895

Benefactor of Industries, Revealer of Mysteries of Disease of Man and Animals and Deviser of Methods for Its Control, Whose Discoveries Have Lessened Suffering and Prolonged Life and Added Immeasurably to the Comfort, Security and Dominion of Man

At the dedicatory exercises Dr. Frank Billings, the chairman of the Pasteur Memorial Committee, presided. Professor Ludvig Hektoen, of the University of Chicago, made an address on Pasteur. M. Paul Claudel, ambassador of France, spoke in behalf of the French people. Mlle. Claudel, the daughter of the French ambassador, unveiled the monument, and finally the monument was presented to the commissioners of the South Parks of Chicago by Dr. Billings and was accepted for preservation by Mr. Edward J. Kelly, the president of the South Parks.

BASHFORD DEAN

Bashford Dean, late professor of zoology in Columbia University, honorary curator of fishes in the American Museum of Natural History, former curator of arms and armor in and a trustee of the Metropolitan Museum of Art, died at Battle Creek, Michigan, December 6, 1928, aged sixty-one years.

Dr. Dean's interest in the two subjects, armor and fishes, in each of which he became a world authority, was manifest early in life—at or before the age of seven. At the age of nineteen he graduated from the College of the City of New York. He then entered Columbia University, where he studied fossil fishes under Dr. J. S. Newberry, and whence he graduated with the Ph.D. degree in 1890, his dissertation being entitled "Pineal Fontanelle of Placoderm and Catfish."

In 1886, Dean was appointed tutor in natural history in the College of the City of New York. In 1891 he was made instructor, in 1896 adjunct professor, and in 1903 professor of vertebrate zoology in Columbia University. During these years he made extensive investigations for the U. S. Fish Commission into the methods of artificial oyster culture in southwest Europe and in Japan, becoming an authority on this subject.

With the appointment to Columbia, Dean began researches in the paleontology, anatomy and embryology of fishes which made him the acknowledged leader in America in these branches of ichthyology. Particularly he extended the work of Newberry on the Devonian armored shark-like vertebrates, and made brilliant embryological studies of three American Ganoids—the bowfin, garpike and sturgeon. Turning to the lower marine vertebrates, he made equally brilliant studies of the embryology of the hagfishes and the silver sharks. Unfortunately he left unfinished similar studies on the embryos of the Port Jackson and of the Japanese frilled sharks. His best-known single work is "Fishes, Living and Fossil" (1905).

As curator of fossil fishes and afterwards of ichthyology in the American Museum covering the period 1903–1910, Dean planned and installed the habitat groups of fossil fishes and of living Ganoids and other fishes in the American Museum which set new standards for museum exhibits of fishes. About this time he began the final bibliographical work which resulted in the publication of the great three-volume "Bibliography of Fishes" (1916, 1917, 1923), by

the American Museum, for which he was awarded the D. G. Elliott medal in 1923.

In 1910, because of his eminence in zoology, Dean was made a Chevalier de la Légion d'honneur. Resigning his curatorship in the American Museum in this year, he was made curator of arms and armor in the Metropolitan Museum, and built up a collection there which to-day ranks fourth of all in the world, and unlike any other is arranged on a strictly evolutionary basis. When our country entered the World War, Dean volunteered for service and was commissioned major in the Ordnance Department. He studied conditions of trench warfare in Europe and engaged in extensive experiments for improving helmets and body armor when the sudden ending of the war came. His final work in the Metropolitan Museum, a "Bibliography of Arms and Armor," is nearly ready for the press.

Dr. Dean was an exceedingly brilliant and versatile man, who, despite the life-long handicap of frail health, wrought prodigiously. His outstanding characteristics were a devotion to science and a love of the beautiful in art. After his retirement he designed, built, and with his own hands decorated a large Gothic hall as an addition to his house at Riverdale, New York. In this he had begun the installation of his private collection of armor, when his call came.